CONTACT

ISSUE 04

JUNE 2020

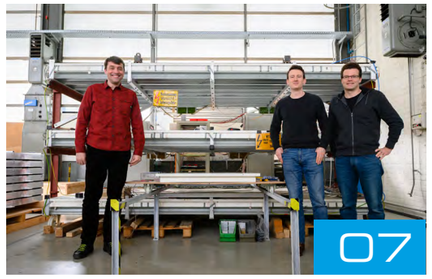
INSIGHTS INTO THE MAX PLANCK SKA DISH PROTOTYPE

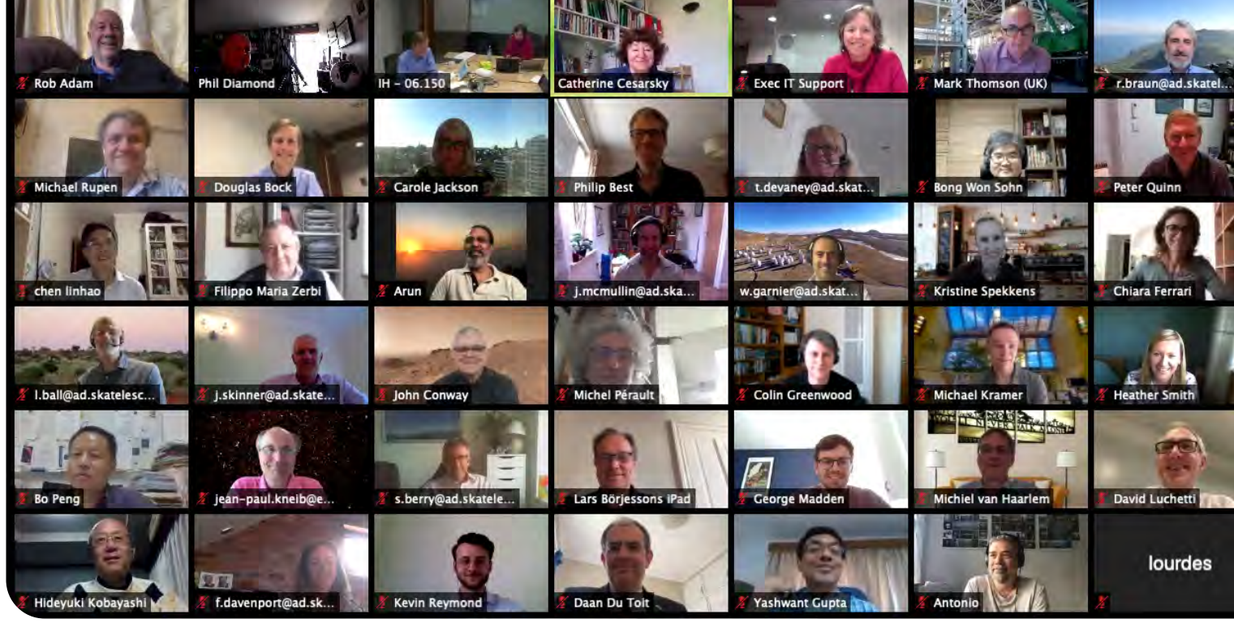
SKA PARTNERS CONTRIBUTE TO PANDEMIC RESPONSE

ASKAP UNVEILS UNIVERSE'S MISSING MATTER

SKA
SQUARE KILOMETRE ARRAY

CONTENTS





A screenshot of the 32nd meeting of the SKA Board of Directors, taking place virtually on Zoom. The notes from the Chair of the Board are available here.

Dear Friends and Colleagues,

Welcome to this, the fourth edition of Contact. The magazine provides some fascinating stories of happenings across the SKA partnership. It is especially uplifting to read these and to see the international collaboration that SKA embodies be so active in these difficult times. As I wrote the introduction for the previous issue of Contact, COVID-19 was severely affecting some countries, and as we all know, it has now spread across the globe. I'm not sure that any of us could have predicted the impact this would have on our daily lives, and the sadness it would bring to so many. I do hope that we are beginning to see positive signs from all that the world's people and governments have done.

In the SKA, as for many activities around the world, we have had to learn a different way of working. The use of Zoom and video-conferencing from home, which has been such a boon to us all, would likely not have been possible just a few years ago. I'm sure we all remember the earlier days of unreliable video-conferencing and low internet bandwidths. It is somewhat ironic that the digital communications revolution which underlies the technology of the SKA, is the same that has made it possible for a good fraction of the world's business to continue during the pandemic.

Within the project, work has continued at pace. The external review of the Operations Plan was a great success, as was the Cost Review conducted by the engineering firm Arup. They, along with the System Critical Design Review completed in March, have given great confidence to me, the senior team at SKAO and our international stakeholders that the SKA is proceeding to construction. Our staff are now heavily focused on finalising the SKA1 Construction Proposal and what we call the Observatory Establishment and Delivery Plan (which combines Operations, the Development Programme and the so-called business-enabling functions, such as HR, Finance, Procurement, Communications etc); these key documents will be submitted to the SKA Organisation Board later in the year for sign-off and will then be passed to the Council of the SKA Observatory, when it has been established.

On that last point, it was extremely gratifying to see, literally as I write this, the press release issued which announces that the Republic of South Africa has ratified the SKA Observatory Convention. South Africa is the third country to ratify, and the first of our three host countries. I am hopeful that we'll see the ratification process completing in other partner countries in the near future.

I hope you and your families remain safe.

Prof. Philip Diamond, SKA Director-General

SWITZERLAND'S EPFL JOINS SKAO

BY SKAO

In April, the SKA Organisation welcomed its 14th member, the Swiss science and technology university École Polytechnique Fédérale de Lausanne (EPFL), following a unanimous decision by the SKA Board of Directors.

EPFL is now the lead institution coordinating involvement in the SKA on behalf of the Swiss academic community*.

Switzerland has a history of world-class research and development in science and astronomy, and at a national level has held observer status within the SKA Organisation since 2016. Swiss-based scientists are active in eight of the SKA's Science Working Groups.

Many Swiss research institutions and industry partners are contributing to various aspects of the SKA, and annual Swiss SKA Days are now in their fifth year, showcasing the breadth of opportunities for others to become involved. The Federal Council also recently triggered the first political debate in parliament regarding Switzerland's possible participation as a member state of the SKA Observatory in the future.

"Switzerland is the proud Seat of CERN and a dedicated member of the European Southern Observatory and of the European Space Agency," said Xavier Reymond, Deputy Director General for International Research Organisations at the State Secretariat for Education, Research and Innovation, who is in charge of the relationship between Switzerland and SKAO. "Therefore, we all look forward to assessing the opportunity to complement these intergovernmental endeavours with the upcoming SKA Observatory, which shares the same dedication to better understanding the Universe."

**The Swiss Academic Community includes Universities of Geneva, Zurich, Bern, ETHZ, CSCS, FHNW, HES-SO, and Verkehrshaus Lucern*

Read more on the EPFL website.

The main EPFL campus in Lausanne sits on the shores of Lake Geneva. Credit: Mediacom EPFL; CC BY-SA 4.0.

SOUTH AFRICA RATIFIES THE SKA OBSERVATORY CONVENTION

BY SKAO

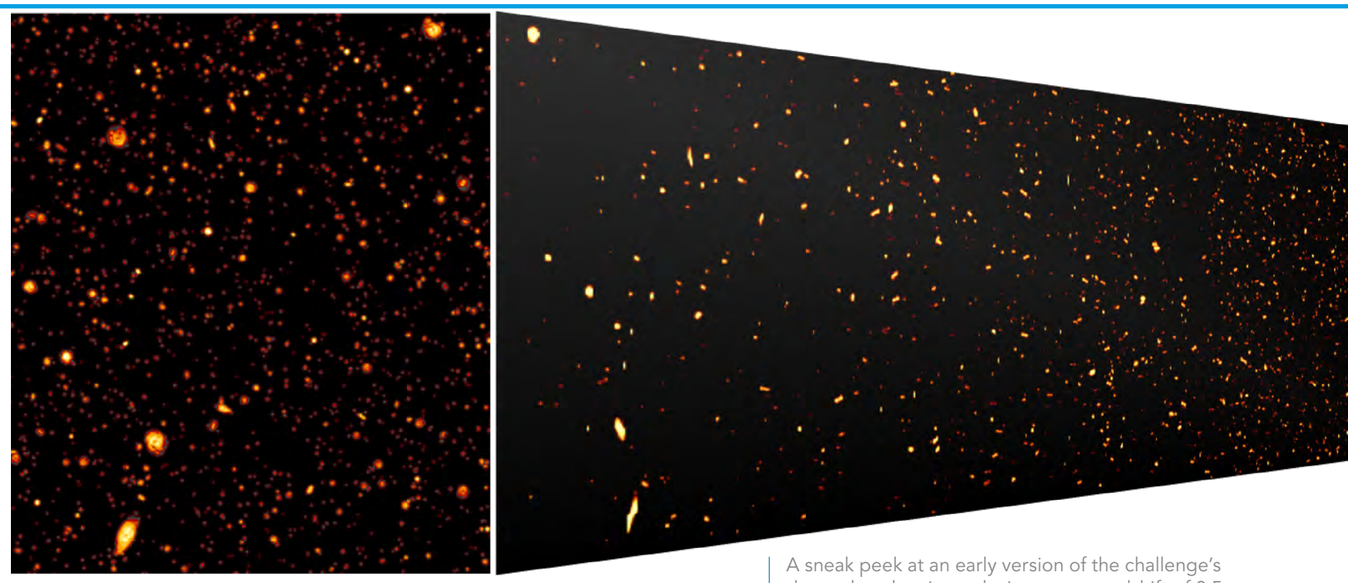
South Africa ratified the Convention Establishing the SKA Observatory at the end of May after the South African Parliament approved the text and Dr Naledi Pandor, Minister of the Department of International Relations and Cooperation, signed the Instrument of Ratification.

South Africa was among the seven countries that signed the Convention in Rome on 12 March 2019, alongside Australia, China, Italy, the Netherlands, Portugal and the United Kingdom. The Convention will enter into force once five countries, including the three hosts Australia, South Africa and the UK, ratify the text.

"This is a significant moment not only because South Africa is the first of our hosts to ratify the Convention, but with multiple countries having done so, we are now closer to the SKA Observatory formally existing," said SKA Director-General Prof. Philip Diamond.

"Even with the terrible toll of coronavirus around the world, countries have shown remarkable commitment to the SKA and continue to push forward. It is testimony to the strength of our global collaboration and the impact the project will have," added Prof. Diamond. "Momentum is strong, and we expect Australia, China, Portugal and the UK to ratify in the coming months, with other countries joining the Observatory in due course. Once the SKA Observatory is up and running, construction of the largest science facility on the planet will begin in earnest." Read more on the SKA website.

Right: then South African Science Minister Mmamoloko Kubayi-Ngubane signing the SKA Convention in Rome in March 2019.



A sneak peek at an early version of the challenge's data cube, showing galaxies up to a redshift of 0.5 – that's a distance of around 4 billion light years. Credit: Dr Philippa Hartley

SKA SCIENCE TEAM GEARING UP FOR DATA CHALLENGE #2

BY SKAO

Preparations are accelerating for SKA's Science Data Challenge 2, which will be launched later this year. The aim of the Data Challenges is to prepare the scientific community for the reality of working with SKA data.

Run by the SKAO Science team, the new challenge will be an HI galaxy simulation in which teams are asked to locate galaxies and discern their properties using mock SKA data. They'll do so by running their own software analysis tools on a 3D "data cube" – a series of stacked radio images, each reflecting a different frequency. Unlike a 2D image, the data cube will allow researchers to determine things like how fast the galaxy rotates, and how much mass it must contain.

This time instead of downloading the data to their own computers, participants will access and process these data using major computing facilities, just as SKA users will eventually have to do via the SKA Regional Centres (SRC). This allows future users to familiarise themselves with the kind of computing environments the SKA will provide.

"Using computing clusters allows us to test that SRC model, and also means we can create a much bigger data set for the challenge, around one terabyte in this case, which otherwise could take weeks to download," says SKA Project Scientist Dr Anna Bonaldi, who is co-leading the work.

The Shanghai SKA Regional Centre Prototype and ENGAGE-SKA Portugal cluster are lined up to store and process the data, and others may join them.

As well as helping the SKA Science and Operations teams to test the model of transferring data back and forth to dispersed computing clusters, the challenge will also start a dialogue between users and the facilities involved to identify any training or additional tools that would be useful.

The SKA HI Science Working Group will soon begin testing and debugging a subset of the data as part of the preparations.

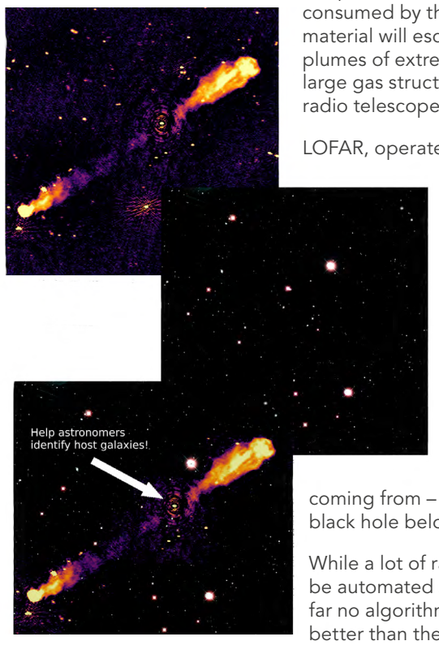
> **"USING COMPUTING CLUSTERS ALLOWS US TO TEST THAT SRC MODEL, AND ALSO MEANS WE CAN CREATE A MUCH BIGGER DATA SET FOR THE CHALLENGE."**
>
> Dr Anna Bonaldi, SKA Project Scientist

LOFAR **SEEKS CITIZEN SCIENTISTS** TO HUNT FOR **BLACK HOLES**

BY ASTRON

Scientists are asking for the public's help to locate the black holes at the centre of hundreds of thousands of galaxies discovered by the Low Frequency Array (LOFAR) radio telescope. The citizen science project, LOFAR Radio Galaxy Zoo, gives anyone with a computer the chance to get involved, and so far more than 4,000 volunteers have taken part.

Radio images show a sky that is very different from that seen by optical telescopes. In the radio sky, stars and galaxies are not directly visible. Instead, an abundance of complex structures linked to the supermassive black holes at the centres of galaxies are detected. For instance, most dust and gas surrounding a supermassive black hole gets consumed by the black hole, but some material will escape, forming large plumes of extremely hot gas. These large gas structures are observed by radio telescopes.



LOFAR, operated by the Netherlands Institute for Radio Astronomy (ASTRON) and celebrating its 10-year anniversary this month, has so far discovered four million radio sources in its ongoing sky survey. A few hundred thousand of these are such complicated structures that it is difficult to determine which galaxies they're coming from – in other words, which black hole belongs to which galaxy?

While a lot of radio data analysis can be automated using algorithms, so far no algorithm can identify shapes better than the human eye. The international LOFAR team consists of more than 200 astronomers from 18 countries, but that's still not enough given the volume of images. That's where the citizen scientists come in! By looking at images where optical and radio observations have been overlaid, they can help to work out which radio sources and galaxies go together.

"This will help researchers understand how radio sources are formed, how black holes evolve, and how vast quantities of material can be ejected into deep space with such unprecedented amounts of energy", says Dr Tim Shimwell of ASTRON and Leiden University.

Radio Galaxy Zoo: LOFAR is part of the Zooniverse project, the world's largest and most popular platform for people-powered research.

Left: From top: radio, optical and an overlay of the two images. Combining the data in this way enables the human eye to link radio sources with their host galaxies. Credit: Aleksandar Shulevski, Erik Osinga & The LOFAR surveys team.

ASTRONOMY OUTREACH GOES VIRTUAL TO SUPPORT **HOME-STAYING FAMILIES**

BY SKAO

As soon as the confinement hit, the international astronomy outreach community scrambled to get involved to help support parents-turned-teachers and people staying at home.

The International Astronomical Union's Office of Astronomy Outreach (IAU OAO) has been coordinating a global response by educators and outreach experts to compile and make material available online, producing an impressive list of free resources available here by age, role and language.

The SKAO Comms team has played its part, refreshing much of our online content since the lockdown started. We updated our Amazing Facts about the SKA, added a list of SKA-relevant citizen-science projects people can get involved in; we added fun new activities developed by our partners using Augmented Reality and Virtual Reality, and we also added a list of activities for children that explain some of the engineering behind the SKA. Last but not least, coinciding with World Art Day and following the example of museums around the world, we made our indigenous astronomy art exhibition Shared Sky available online for all. You can now enjoy all of the artworks in the collection in our virtual gallery from the comfort of your home.

PARTICLE DETECTOR FOR SKA-LOW CALIBRATED IN GERMANY

BY JUSTIN BRAY (THE UNIVERSITY OF MANCHESTER)

A new particle detector designed to enable SKA-Low to study cosmic rays, the highest energy particles in nature, has undergone testing in Germany.

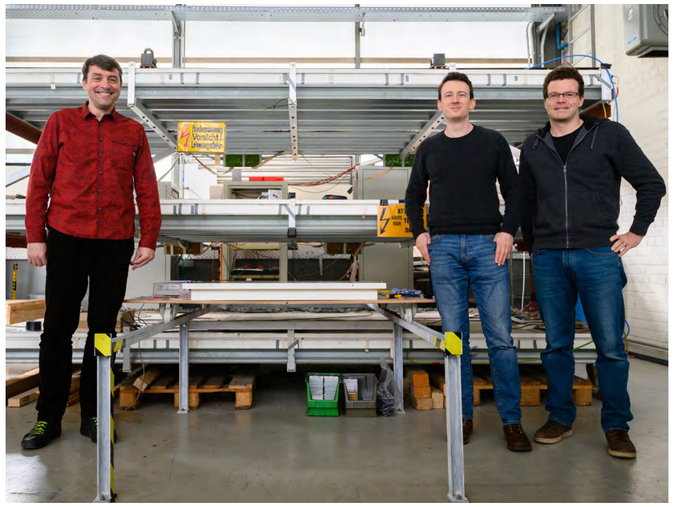
Developed by a team at the University of Manchester in the UK, particle detectors like this one are to be deployed in the core of SKA-Low at the Murchison Radio-astronomy Observatory in Western Australia. They will allow the SKA High Energy Cosmic Particles Focus Group to study the spectrum and composition of cosmic rays.

Cosmic rays travel through space almost at the speed of light, but when they hit the Earth's atmosphere, they disintegrate into a cascade of high-energy particles. By recording the radio emission from this cascade with SKA-Low, and the particles themselves with an array of these detectors, it is possible to determine the properties of the original cosmic ray.

The detector contains a panel of scintillator material – that's a substance which, when struck by a high-energy particle, creates a pulse of light. This pulse, only a few nanoseconds long, is then detected by cutting-edge silicon chips designed to respond to even a single photon of light.

The recent tests were performed at Karlsruhe Institute of Technology (KIT) in Germany, which has the facilities and expertise to more precisely measure the performance of the final design. KIT also provided the scintillator material, used in an earlier cosmic-ray experiment called KASCADE.

An array of a further eight detectors, funded by a grant from the Australian Research Council, will be deployed by staff at Curtin University, using a backend developed by CSIRO Astronomy & Space Science.



Images: Tim Huege

CELEBRATING **NATIONAL SCIENCE DAY** IN INDIA

BY NCRA

Like every year for the past 18 years, the National Centre for Radio Astrophysics (NCRA) took part in India's National Science Day celebrations in late February, organising one of the largest Science Day events in the country at the Giant Metrewave Radio Telescope (GMRT) near Pune.

Working models and projects produced by hundreds of students from various districts of the state were on display, alongside exhibits and demos from several research organisations, as well as a full array of exhibits and live demos on GMRT and astronomy.

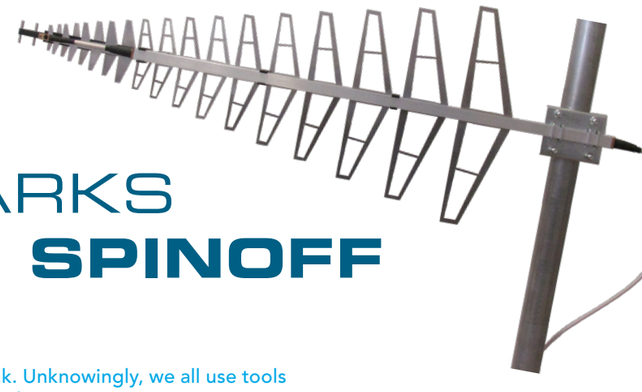
The annual event provides an excellent opportunity to visit the GMRT Observatory, which is only open to the public on that occasion. Every year, the event attracts a footfall of over 20,000 visitors.

Images: NCRA

A NEW TRAILER FOR NCRA

The American Physical Society (APS) commissioned a short video documentary about our Indian partners NCRA, featuring their facilities and research. Take a look:

SKA-LOW PROTOTYPE ANTENNA SPARKS **COMMERCIAL SPINOFF**



BY DARIA GUIDETTI (INAF)

Astrophysics is not as far from our daily lives as one might think. Unknowingly, we all use tools inspired by instruments initially developed for astrophysical applications.

A recent example within the SKA realm is the "Christmas tree" SKALA4.1 antenna developed for the SKA-Low telescope, now installed at the Murchison Radio-astronomy Observatory in the Australian outback and which has just inspired a commercial spin-off. The antenna was developed by the Italian National Institute for Astrophysics (INAF) in collaboration with CNR-IEIIT and the Italian industrial partner Sirio Antenne, building on previous designs by an international consortium involving UK and Dutch partners (see details in the "Did You Know" section on p19).

Taking inspiration from this antenna and thanks to the new technical skills they've gained in their two-year cooperation with INAF and CNR-IEIIT, engineers from SIRIO Antenne have developed a new commercial antenna working at 4G-LTE frequencies (698-2700 MHz). This new antenna brings together a broad-band sensor with high gain, good impedance matching and a compact size. It obtained good feedback from the European market and won a tender in France for the electrical network supplier.

The technical and electrical design of the antenna has been strongly influenced by the experience gained by SIRIO Antenne in the SKA. Even though they have very different purposes, the antennas have several common elements, including the materials used – aluminium alloys and plastics. Sirio Antenne are also working to develop a similar antenna for 5G (698MHz – 6GHz), which is now under mechanical study.

"Combining the academic world with the industrial one, the SKA turned out to be extremely interesting and exciting both professionally and from a human experience," says Stefania Grazioli, Director of Sirio Antenne. "The cooperation enriched both sides leading to goals otherwise difficult to achieve."

Image: Sirio Antenne Srl

PORTUGUESE SKA WHITE BOOK **RELEASED**

BY SKAO

The white book summarising Portugal's interests in the SKA from science to computing, industry and societal impact has now been published.

The book stems from contributions presented at the Portuguese SKA Days held on the 6th and 7th February 2018 and attended by Manuel Caldeira Cabral, then Minister of the Economy; Paulo Ferrão, then President of the Fundação para a Ciência e Tecnologia (FCT- Science and Technology Foundation); as well as Daan du Toit, Deputy Director-General of the South African Department of Science and Technology; Alistair McPherson, then SKA Deputy Director General; Robert Braun, SKA Science Director; and advisors to the Ministry of Science and Technology and Higher Education Cabinet and other organisations.

This initiative was held to promote the SKA among the Portuguese scientific and business communities with support from the FCT and the contribution of Portuguese policy makers and researchers.

The meeting was very successful in providing a detailed overview of the SKA status, vision and goals and describes most of the Portuguese expected contributions to science, technology and the related industry aspirations.

The book is available here.

DID YOU KNOW?

Two more "white books" have recently been published, including the Chinese SKA Science Book, a thorough summary of which is available here, and the updated SKA-JP Science Book for 2020, which since 2015 has seen a doubling of the number of authors involved and more than 130 new pages added, demonstrating the interest of the Japanese scientific community in the SKA!

SKA FREQUENCY AND TIMING TESTING AT THE UNIVERSITY OF MANCHESTER

BY PROF. KEITH GRAINGE AND DR ALTHEA WILKINSON (THE UNIVERSITY OF MANCHESTER)

The Radio Astronomy Advanced Instrumentation Research (RAAIR) Laboratory at the University of Manchester is a university-industry collaboration run by the university's Department of Physics and Astronomy and Department of Electronic and Electrical Engineering.

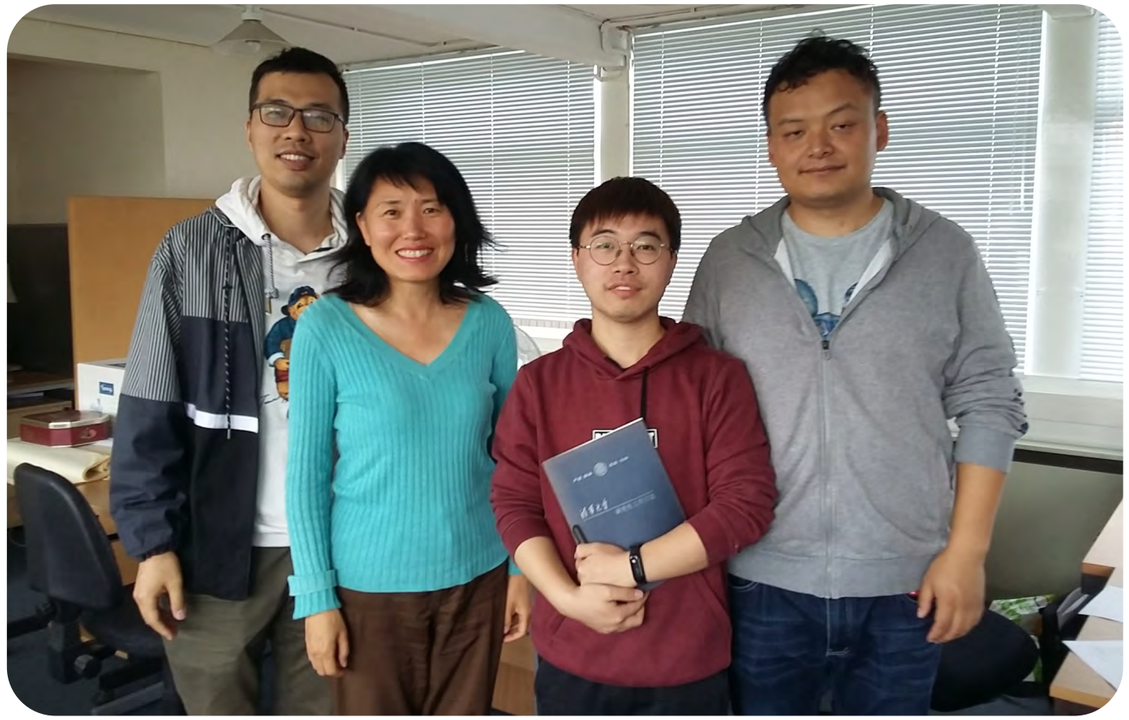
As part of a Time & Frequency Systems project funded by the RAAIR Laboratory, engineers from Tsinghua University in China have been visiting the SKA Synchronisation and Timing (SAT) team at the University of Manchester, to develop and test potential new frequency and timing transfer systems for the SKA-Low telescope in Australia.

Professor Bo Wang and his research student Yufeng Chen are working with the SAT team to test their system, developed at Tsinghua University, which provides a novel, on the fly, active phase correction to mitigate the effects produced as optical fibre expands and contracts with temperature. The team, including RAAIR Engineers Ji Zonghai and You Lu, is also integrating the White Rabbit open source hardware system so that both frequency and timing information can be transferred over a single fibre.

The system is being tested as a potential prototype for the SKA pathfinder e-MERLIN telescope network (which is operated by the University of Manchester on behalf of the UK's Science and Technology Facilities Council), which only has a single fibre available, but will also act as a test-bed for application to the SKA.

The Tsinghua system is being tested over distances between 20 and 80 km and the results indicate a high level of accuracy, confirming that the system is working at the levels required for SKA-Low. Similar work is also being undertaken by Australian teams working on the SKA-Mid telescope.

Professor Michael Garrett, Director of the RAAIR Laboratory and the Jodrell Bank Centre for Astrophysics said: "Accurate time distribution is critical to the operation of radio telescopes like the SKA, permitting signals detected by pairs of antennas to be coherently combined, enabling the array to act as an interferometer. This is at the very heart of the SKA design, since it makes the required sensitivity of the telescope feasible by allowing signals from multiple antennas to be combined, giving the telescope its power to resolve small features on the sky. This collaboration shows how much can be achieved when universities team up with industry partners – I'm absolutely thrilled by the first results."



RAAIR team members; Ji Zonghai, Lydia Kong, Yufeng Chen and You Lu. Credit: The University of Manchester

AROUND THE WORLD, SKA PARTNERS CONTRIBUTE TO PANDEMIC RESPONSE

BY MATHIEU ISIDRO (SKAO)

Before we really had time to prepare, the pandemic was here. As governments around the world scrambled to respond, societies had to quickly adapt to a new normal and the enormous challenges that would need to be overcome to address the crisis became apparent. In response, while continuing to deliver on its primary mission, the global SKA community has been making full use of its diverse set of skills to help in a variety of ways. Here's a non-exhaustive overview of how our partners have contributed around the world.

In South Africa, the Department of Trade, Industry & Competition (DTIC) called on companies and experts, particularly engineers and scientists, to come forward with innovative solutions to design, develop, produce and procure respiratory ventilators. They tasked the South African Radio Astronomy Observatory (SARAO) to oversee the design and production of such ventilators in the country "based on the experience SARAO gained in the development of complex systems for the MeerKAT radio telescope."

Indeed, with a shortage of key machines like ventilators in many countries, the skills of project managers, technicians and engineers have proved essential – skills like those of SARAO's young mechanical engineer Nathaneal Morgan who's involved in the ventilator project (read our profile on page 32).

Shortly before this article went to print, the DTIC Minister Ebrahim Patel announced that three prototypes were being finalised and production would start this June, ramping up to 20,000 by August.

Testing and calibration of these new ventilators to make sure they work as intended is also key. In the UK, "super trainers" from our partners the Science & Technology Facilities Council (STFC) have been supporting the VentilatorChallengeUK Consortium, which involves more than 20 companies including Airbus, Ford and McLaren to produce ventilators on a large scale, by developing a ventilator training manual and training staff so they can instruct others by the time the ventilators come off the production line.

It's not just ventilators, but also other innovative tools that are needed in the face of the COVID-19 crisis. In Spain, the Institute of Astrophysics of Andalusia's Cosmic Dust Laboratory – usually busy studying how cosmic dust particles diffract light in planetary and comet environments – has joined a consortium funded by the Ministry of Science & Innovation to develop a portable prototype that can detect the presence of COVID-19 on surfaces using optical technology and artificial intelligence.

Like engineering skills, supercomputing facilities have been in high demand. STFC have been providing high-performance computing capability to the Folding@Home project through their Hartree Centre to power simulations of protein behaviour and help identify drugs that could be used to treat COVID-19.

"While there is lots of compute power available to run the simulations, analysing the results requires the specialist hardware of a dedicated supercomputer," says Alison Kennedy, Director of STFC Hartree Centre. "The simulations then aid in the understanding of diseases and the discovery of potential treatments or therapeutics."

DID YOU KNOW?

One of the Hartree Centre's main goals is to develop energy efficient computing technologies, as well as data intensive computing for the SKA.

YOU CAN HELP TOO!

The Folding@home project is playing an essential role in understanding the mechanisms of disease, and most importantly COVID-19, by bringing together a community of 'citizen scientists' who are volunteering to run simulations of protein dynamics on their personal computers. While you keep going with your everyday activities, your computer will be working to help find cures for diseases like cancer, ALS, Parkinson's, Huntington's, Influenza and many others. Find our more here.

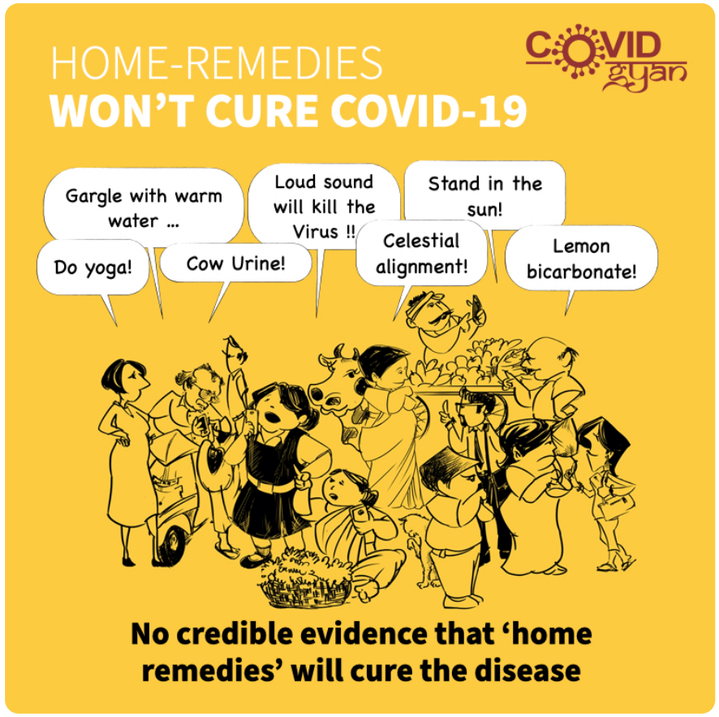
In Australia, astronomers have also been lending their coding and data skills. Researchers at Swinburne University including Prof. Matthew Bailes, a member of the SKA's Pulsar Science Working Group, developed a Symptom Tracker app in collaboration with the university's Astronomy Data and Computing Services team. The app allows users to log their health and – using supercomputers usually dedicated to astrophysics – identify emerging clusters of symptoms where COVID-19 could be spreading. [...]

The response to the pandemic hasn't just been technological, but also informational. With so many unknowns about this novel virus and misinformation circulating widely via social media, the need for accurate and reliable science communication has been essential.

In India, our colleagues at the National Centre for Radio Astrophysics (NCRA) are part of CovidGyan, a multi-institutional, multi-lingual science communication initiative led by their umbrella institute the Tata Institute of Fundamental Research, which sits under the government's Department of Atomic Energy, to provide a reliable source of factual information while filtering out misinformation. The site includes infographics (see an example below), podcasts, webinars as well as articles to explain what we know and debunk myths in accessible ways.

The astronomy community, well-versed in public outreach, has also stepped up to help with education, with up to half of the world's population in lockdown at the height of the international response and many school children having to be home-schooled. The IAU's Office of Astronomy Outreach (OAO) has been coordinating an international effort to gather free digital astronomy resources and fun activities to do at home to keep children occupied and entertained which SKAO have contributed to, while in Italy our partners the National Institute of Astrophysics (INAF) have been developing educational videos including lectures & virtual tours to be made available on a national online platform under the Ministry of Education & Research. In the UK, STFC has been running a campaign on social media called #STFCScienceatHome, engaging with over 4,000 people during their Telescope week featuring SKA.

The current crisis is far from over, and the hunt for treatment and a vaccine goes on, but as the world slowly learns to live with COVID-19, it's been heartening to see the SKA community step up and contribute to the global effort. Far from clichés of astronomy being stuck inside an ivory tower, these efforts by organisations, scientists, engineers and educators are a prime example of how astronomy, with its highly skilled and creative workforce, can give back and contribute to society in immediate, tangible ways… in addition to inspiring millions by unraveling mysteries about the Universe.



PPE has been in short supply globally, and so institutes and laboratories equipped with 3D printing machines have also been chipping in, providing much-needed equipment for frontline workers.

THE DARA PROJECTS: TRAINING **A NEW GENERATION** OF AFRICAN SCIENTISTS

BY LINZI STIRRUP (THE UNIVERSITY OF MANCHESTER)

Two projects linked to the SKA and funded by the UK and South Africa are helping to train young Africans in radio astronomy and data science, with the aim of ensuring that they are able to take advantage of the enormous opportunities that radio astronomy will bring.

The DARA (Development in Africa with Radio Astronomy) project was set up in 2015 by Prof. Melvin Hoare of the University of Leeds, to train a first generation of radio astronomers in the eight SKA African partner countries: Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia and Zambia. Most of these countries had very few or no astronomers until recently.

"I originally started this with a small Royal Society funded project in Ghana where the South African SKA team were carrying out the first telecommunications dish conversion into a radio telescope," comments Prof. Hoare. "Once the Newton Fund came along then the opportunity to scale up into the major international project to help prepare for the SKA was there and it has taken over my life in a very positive way."

Two years later the DARA Big Data project was set up by Prof. Anna Scaife of The University of Manchester to train students in data science and machine learning, both of which will be vital to translate the massive quantities of data produced by projects like the SKA.

"I was inspired by the talent and ambition of the students that I met while tutoring on various training programmes in different African countries," says Prof. Scaife. "The students could already see the wider benefits of the skills they were acquiring through radio astronomy and I wanted to build a programme which reflected that."

Both projects are run jointly by the UK and South Africa and are funded by the Newton Fund, which taps into the UK's overseas aid budget for scientific collaborations with developing countries representing £6.3m of UK funding since 2015, and matching resources from South Africa where key organisations such as SARAO (South African Radio Astronomy Observatory) and the DSI (the Government's Department of Science & Innovation) are heavily involved and have a keen interest in the projects.

DARA and DARA Big Data work closely with each other and facilitate a strong pan-African network between the students, and it is hoped that this will continue throughout their careers.

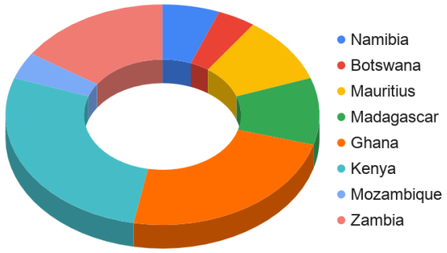
Throughout the eight African partner countries, DARA has provided basic radio astronomy training to more than 250 young graduates in the form of four two-week training courses delivered by experts from the UK and South Africa over the course of a year. DARA Big Data has run hackathons and intensive workshops for almost 200 students. Both projects also provide funds which fully cover students to study at Masters and PhD level at universities in the UK and in South Africa; DARA has 32 students who have either completed or who are still studying, while DARA Big Data has 18.

All of the trainees have also been exposed to vital industrial opportunities via partners such as the UK's Goonhilly Earth Station, once the largest satellite station in the world and now a major commercial space communications site, or from inspirational figures working at high levels in data science or scientific policy. Among them, former Director of SKA South Africa Dr Bernie Fanaroff, and leading international advisor on scientific diplomacy Dr Marga Gual Soler. [...]

DARA and DARA Big Data students and staff at Goonhilly Earth Station in Cornwall, December 2019. Credit: Tom Young

DARA IN THE TIME OF COVID-19

During the pandemic both projects remain frequently in touch with students and are making sure they are supported. Future students may begin their courses remotely, depending on how things develop. DARA Big Data is also currently developing an online hackathon to be held later in the year in one or more of the SKA African partner countries.



50 students from all eight SKA African partner countries have studied in the UK through the DARA and DARA Big Data postgraduate programme

The students are very active in their fields and are already high achievers before they even start their postgraduate courses. There is fierce competition to be accepted onto the advanced programmes; each call for students receives up to 10 times more applications than there are places available. DARA students are spread out between eight participating UK universities and regular events are organised to get them all together as often as possible. The most recent of these in February 2020 was the Fanaroff Lecture, named after Dr Bernie Fanaroff – who was in attendance – delivered by Dr Marga Gual Soler. DARA and DARA Big Data students attended the lecture and the following private dinner, giving them direct access to some key figures in the scientific community as well as a chance to socialise with each other.

In December 2019, 20 students attended the first Advanced Student Event for both DARA and DARA Big Data in the UK's south-western region of Cornwall, at Goonhilly Earth Station. The event, which will become a regular occurrence, encourages a collegiate network to form and gives students the chance to present their research to each other.

The two DARA projects have been recognised in both the UK and Africa for their great success and visible progress. A ministerial statement representing South Africa and the SKA African partner countries said that DARA "is making valuable contributions to strengthen radio astronomy in partner countries", adding: "DARA courses are important for capacity building in high performance computing and data science, key technologies to support and develop radio astronomy."

Takalani Nemaungani, Acting Chief Director of Astronomy at the Department of Science & Innovation, said it is "a testimony that astronomy can contribute to the broader societal needs of the continent".

"I am grateful that our partnership with the UK, through the Newton Fund and the DARA initiative, is equipping a new generation of entrepreneurs, scientists and professionals," he said.

Read more about both projects on their websites: https://www.dara-project.org and https://www.darabigdata.com.

ANALYSING THE IMPACT OF THE SKA ON SCIENCE POLICY IN AFRICA

JEKONIYA CHITERERKA, PHD STUDENT AT THE UNIVERSITY OF LEEDS.

Jekoniya hails from Zimbabwe and is a PhD student at the University of Leeds in the UK. His thesis is on science, technology and innovation policy in Africa, using the SKA as a case study, and he visited SKA HQ earlier this year to meet the Strategy team.

"One of the things I'm looking at is the benefit of all this investment in astronomy, economically, socially and politically. I'm also looking at the impact in terms of governance.

Visiting SKA HQ has enlightened me in a lot of spheres. I've had a real insight into the dynamics involved in managing such a big science project, the potential benefits that can be accrued from this endeavour, and how the players involved interact. We used to call it blue skies research but to me there are now immediate benefits that I can pinpoint, for example we discussed WiFi and its link with radio astronomy. We also talked about how we foster engagement between science and society, so the public appreciates this kind of investment.

The impression I got from the DARA and DARA Big Data programmes is that they are laying a strong foundation and building a critical mass of skills towards the 4th Industrial Revolution in Africa with artificial intelligence (AI) solutions which may have a direct impact on science, technology and innovation policy and how national governments link that to their development plans. Hence astronomy is viewed as playing an enabler role.

The main takeaway for me is that implementation of a big science project is not a walk in the park; it's a complex thing on its own and the number of stakeholders involved also affects the dynamics. The governance of science itself, and trying to have a common ground, that's not an easy task. It takes a lot in terms of diplomacy, a lot of negotiation skills and managing expectations. For governments to get involved in such projects it requires a lot of influencing and making a case for science among competing interests."

> "IT IS A TESTIMONY THAT ASTRONOMY CAN CONTRIBUTE TO THE BROADER SOCIETAL NEEDS OF THE CONTINENT."
>
> Takalani Nemaungani, Acting Chief Director of Astronomy at the Department of Science & Innovation

MEET THE STUDENTS

DR WILLICE OBONYO FROM KENYA, UNIVERSITY OF LEEDS

THE FIRST DARA PHD GRADUATE

"The decision to undertake the DARA basic training in Kenya in 2015 was one of the best of my life. I met friends with an interest in astronomy and trainers who are always ready to support aspiring African astronomers. Subsequently, I became the first DARA-funded PhD student to graduate. I developed close ties with DARA and DARA Big Data students from SKA African partner countries, which facilitated my current internship in scientific computing at the University of Manchester. From October I will take up a SARAO Postdoctoral Fellowship at the University of Pretoria to work on MeerKAT galactic plane survey data."

SIMON NDIRITU FROM KENYA, THE UNIVERSITY OF MANCHESTER

THE FIRST DARA BIG DATA GRADUATE

"I studied electrical and electronic engineering in Kenya. It was while working as a freelance electronics engineer that I realised the demand for data scientists was growing exponentially. I did a DARA Big Data-funded MSc focused on the use of machine learning to reconstruct missing data; I developed a novel algorithm for imputing missing polarisation data based on Gaussian Processes. I am currently pursuing my PhD at the Max Planck Institute in Munich, Germany, researching numerical modelling to study the structural and statistical properties of cosmic magnetic fields. There are many opportunities in Africa just waiting for people with expertise in machine learning and deep learning to unlock and exploit them."

DEBORAH AKUOKO FROM GHANA, THE UNIVERSITY OF MANCHESTER

NOW BUSY WORKING IN INDUSTRY

"I completed an MSc in Information and Communications Technology in Ghana and started working as a systems administrator. I then undertook my DARA Big Data MPhil in Cancer Science. My project looked at the application of big data for improving and personalising breast cancer treatment; I learned clinical image processing and was exposed to world-class professors and experts. Currently I am working as a dev-ops engineer in London with one of the UK's big four companies which I find very exciting. My dream job is to help solve global problems especially in health, starting with my home country of Ghana. I want to solve these problems using data and scientific research approaches."

DALISO BANDA FROM ZAMBIA, UNIVERSITY OF OXFORD

THE FIRST DARA PHD STUDENT TO RETURN HOME

"After completing DARA basic training, I was awarded a DARA studentship to pursue a DPhil focused on radio astronomy instrumentation. This was a natural choice for me as it enabled me to combine two disciplines that I am very passionate about: engineering and the study of the Universe. My work has involved designing a feed horn and transducer that are compatible with the SKA dish optics and the corresponding radio frequency electronics architecture. I am currently putting the finishing touches to my thesis in Zambia and will shortly return to the University of Zambia to carry out teaching and research in microwave engineering and instrumentation."

DR NAOMI ASABRE FRIMPONG FROM GHANA, THE UNIVERSITY OF MANCHESTER

DARA'S ASTRO-CHEMIST

"My love for chemistry began at a young age, which led me to major in chemistry during my studies in Ghana. I became fascinated with astronomy when Ghana got involved in the overall SKA Programme and I signed up for the DARA training in Ghana immediately. After that I undertook a DARA-funded PhD in Astro-chemistry using ALMA data. I am happy I have been able to combine my love for chemistry with this fascinating area of research. I plan to continue with my research in Ghana and to be involved in science outreach to encourage young women in pursuing science."

EMMANUEL NGONGA FROM ZAMBIA, UNIVERSITY OF YORK

AN AGRICULTURAL DATA SCIENTIST

"I saw the endless possibilities that data science offers to 21st Century challenges. My DARA Big Data MSc involved researching ways to improve the pace of soybean breeding in Zambia using satellite imagery, allowing me to predict the maximum potential yield and maturity period of each soybean variety. Currently I work as a part-time Computational Physics tutor at the University of Zambia and am looking for AI PhD studentships. Africa's population is rising exponentially while its climate is changing and it faces significant technological disruption; this will present the continent with complex challenges that only those with skills in machine learning and data science will be well placed to take on."

Images: Tom Young, Simon Ndiritu and Deborah Akuoko

INSIGHTS INTO THE SKA-MAX PLANCK DISH DEMONSTRATOR

BY PROF. MICHAEL KRAMER AND DR HANS-RAINER KLÖCKNER (MAX PLANCK INSTITUTE FOR RADIO ASTRONOMY)

Following the accession of the prestigious German Max Planck Society (MPG) to the SKA Organisation last year, its president Prof. Martin Stratmann visited the South African SKA site in January 2020, stopping by the MeerKAT telescope and the MPG-funded SKA dish demonstrator to see the Max-Planck-Institut für Radioastronomie investments in the SKA for himself. Here's how we got to this point, and what lies ahead for the SKA-MPG dish.

What does it take to turn the SKA from an idea into reality? Early years of detailed design work in the project not only consisted of paper design; in the SKA Dish consortium, they involved the actual manufacturing of prototype dishes from teams in Canada, China and South Africa. In 2014, building on this work and following the recommendations of a committee of independent experts, the SKA Dish design consortium selected the final design for the SKA dish, jointly developed under the lead of the German company MTM and CETC54 from China.

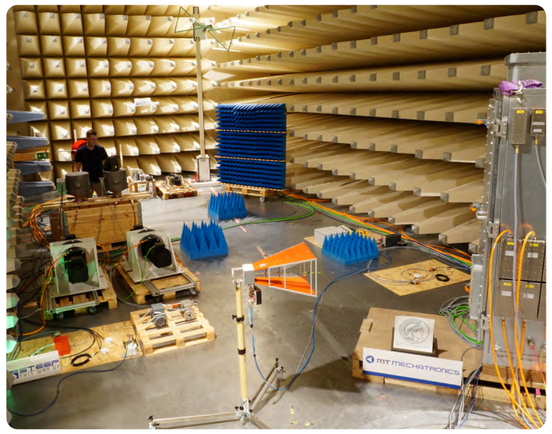
To give the Dish consortium fresh momentum, in 2015 the Max Planck Society increased their activity by funding a cooperation of the Max-Planck-Institut für Radioastronomie (MPIfR) and MTM to build a second dish, the so-called SKA-MPG dish demonstrator in addition to a first prototype funded by CETC54.

Above: Group photograph in front of the SKA-MPG dish demonstrator with the president of the Max Planck Society, Martin Stratmann during his visit in South Africa (from left to right: Justin Jonas, Dave Horn, Daan Du Toit, Willem Esterhuyse, Rob Adam, Sebastian Hoepfner, Bill Hansson, Martin Stratmann, Michael Kramer, Gundolf Wieching, Lisette Andreae, Sias Malan). Credit: SARAO

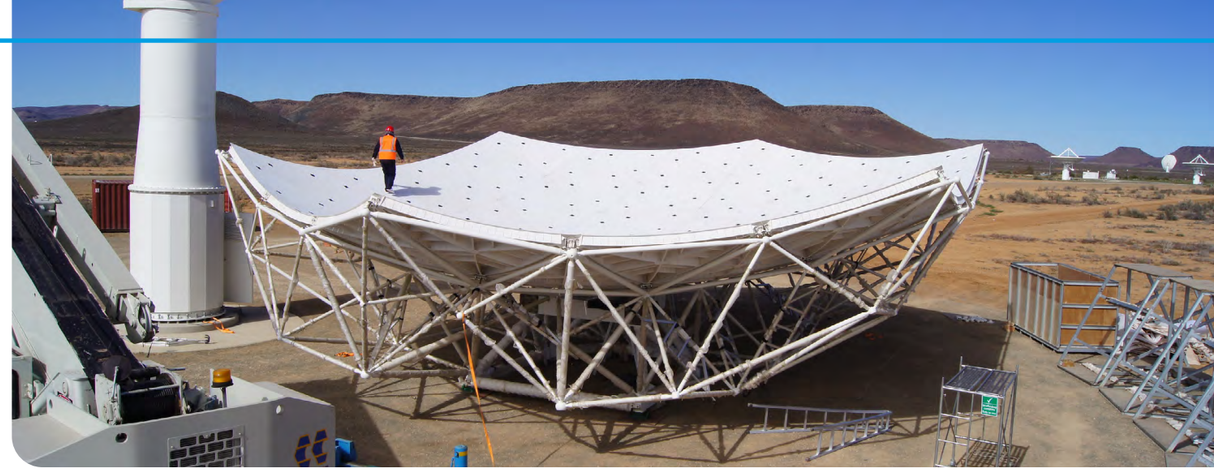
Following the successful outcome of the Detailed Design Review for the SKA dish in China in November 2016, the two dishes were manufactured. The first one, SKA-P, was inaugurated in February 2018 at the CETC factory plant in Shijiazhuang, China, while SKA-MPG was shipped out to the South African SKA site in the Karoo to be assembled and commissioned in real site conditions.

Location, location, location

That decision was made in close partnership with the South African Radio Astronomy Observatory (SARAO) and with the long-term scientific interests of the MPG in mind. Installing the dish on the radio-quiet Karoo site would allow the operation of this demonstrator under realistic SKA conditions, providing valuable lessons for the team to learn from.



Final Radio Frequency Interference (RFI) qualification tests of the redesigned drive system at the MPIfR test facility in Bonn, conducted by MPIfR and MTM. Credit: C.Leinz/MPIfR



Parts of the SKA-MPG dish demonstrator before the final mounting on site in the Karoo area. The image shows the parabolic dish of 15 m diameter in the centre to be mounted on the pedestal on the left. Credit: SARAO

The MPG has used a similar strategic approach in the past to invest in prototypes such as the APEX telescope – a modified prototype of the ALMA antennas located on the same site in Chile – a joint venture by the MPIfR, the European Southern Observatory, and the Onsala Space Observatory.

Progress and setbacks

The installation of the SKA-MPG dish demonstrator started in mid-2018 on a dedicated foundation provided by SARAO close to the MeerKAT telescope core.

The action wasn't just limited to site, though, as pre-qualifying tests of the various subsystems also kicked off among SKA partners around the world. These tests are conducted to ensure parts meet SKA specifications, but also respect the stringent radio frequency interference (RFI) requirements in place at the South African SKA site, which are designed to protect MeerKAT from interference.

Unfortunately, the thorough RFI testing of the dish's drive system upon arrival in South Africa threw a spanner in the works, revealing a need for a significant redesign. Such setbacks are not unusual in projects as complex as the SKA – in fact it is what makes them so fascinating from an engineering point of view! With no solution available "off the shelf", the engineering team of MTM and the MPIfR got back to work to overcome this formidable challenge themselves. After all, when you're building the world's most sensitive radio frequency telescope you need the quietest RFI drive system. The redesign was due to be completed in April 2020, but COVID-19 restrictions have caused some inevitable delays; the impact on the schedule is currently being assessed.

Nevertheless, the assembly of the structure was successfully completed in parallel at the end of 2019, giving us the first tantalising view of an SKA dish on site in the Karoo. MTM has been working with the SKA Dish consortium to conduct various design verification tests, some of which have already been completed successfully, while others are awaiting the RFI-based upgrade of the drive system.

Big plans

Apart from being a technological test facility in which every component of the SKA dish system can be evaluated, the SKA-MPG dish demonstrator also offers a unique opportunity for science. MPG's vision for the dish is that it could be used as a single station or as part of a Very Long Baseline Interferometry (VLBI) network in conjunction with other radio telescopes on the African continent. Although with its 15m diameter it cannot compete with the sensitivity of other Southern Hemisphere telescopes, such as MeerKAT and Australia's Parkes, it offers a rare combination of a large field of view – and so fast sky coverage – with excellent polarisation properties and fast response times. In other words, it offers a broad range of scientific applications.

In preparation for such scientific observations, the MPIfR has designed and constructed two cryogenic receivers with integrated digitisation based on the successful design of their new S-band system for MeerKAT. One of the receivers operates at S-Band (1.75 GHz – 3.5 GHz), while the other operates at Ku-Band (12.0 GHz – 18.0 GHz). Additionally, MPIfR have developed a dedicated system to enable remote observations.

A science programme making the most of the dish's capabilities has been developed, which includes studying the nature of variable sources like active galactic nuclei (AGNs) or fast radio bursts (FRBs), monitoring strong pulsars for rotational or magnetospheric events, investigating the inner workings of FERMI-detected bursts as part of a small VLBI telescope array, and improving our understanding of the foreground to the cosmic microwave background. Precise measurements of this foreground which contaminates the cosmic microwave background is a major challenge for the field in general, which can be tackled by using S-Band receivers like the one developed by MPIfR to conduct full Southern-sky surveys. A large fraction of the observing time on the dish would be dedicated to such surveys, but a call for observations open to the South African and German community is also in the works, as well as an opportunity to set up a teaching programme for schools and universities.

The telescope could also be used for the future R&D programme of the SKA Observatory. Every component necessary to the SKA dish system, from the structure to the receiving system, data transport, data analytics and quality measures, can be developed and tested on the SKA-MPG demonstrator. This is what makes prototypes such valuable.

LESSONS LEARNED FROM BUILDING A TELESCOPE IN THE OUTBACK

BY ICRAR AND INAF

A few months ago, Italian and Australian researchers completed the deployment of a full 256-antenna SKA-Low station at the Murchison Radio-astronomy Observatory, the future home of SKA-Low in Western Australia. The year-long work on site taught them valuable lessons about the behaviour of antennas on the ground, with a few extra insights thrown in...

In late 2018, the International Centre for Radio Astronomy Research (ICRAR) and Italy's National Institute for Astrophysics (INAF) set themselves an ambitious goal to simulate, deploy and commission a full station of 256 SKA-Log periodic Antennas (SKALA) within a year, in order to mitigate the risks associated with station-level calibration that had been identified in the lead-up to the SKA's System Critical Design Review.

"If you can't calibrate the individual stations properly, you don't know how accurately your station beam has been formed. This will impact on the overall SKA-Low array beam, and hence how good your observation is, so it's a vital part of preparation for the SKA. This is especially true for the sensitive science SKA-Low will conduct, such as work on the Epoch of Reionisation, which seeks incredibly faint signals hidden behind much stronger ones," said Professor David Davidson, Director of Engineering at ICRAR.

By May 2019, a smaller station consisting of 48 SKALA antennas version 4.1 was on site, and commissioning work commenced almost immediately. By the end of the year, the full station was in place, and data was being captured and processed. The demonstrator, known as the Aperture Array Verification System 2.0 (AAVS2.0), was deployed by researchers from ICRAR and INAF, as part of SKAO-led bridging activities. Its 256 antennas are distributed on a wire-mesh ground, with a maximum distance between them of 38 metres.

The array layout is semi-random, with some antenna positions fine-tuned for mechanical and practical reasons.

The team then simulated the electromagnetic behaviour of the array components, to predict the station beams (the method by which SKA-Low will view the sky) and other antenna parameters key to understanding the performance of the telescope. They assessed the interference level between the individual antenna beams due to the large number of antennas within such a small diameter, creating so-called 'Embedded Element Patterns'. The full station beam generated by these patterns differs from the ideal stand-alone one, which is computed with simplified models not including the interactions between antennas.

"Having an accurate field validation of the antenna numerical patterns computed in very realistic scenarios, considering for instance the mutual coupling between antennas, is very important before trusting the simulated model," explains Dr Pietro Bolli, Antenna Researcher at INAF.

"It would be impossible to experimentally characterise more than 130,000 antennas in such wide frequency range, so scientists have to rely on antenna models. At the same time, we cannot run electromagnetic models without having proved at least for some frequencies and for some antennas that their results match with high fidelity to the measured responses. This is where the drone measurement entered in the game."

The researchers were able to achieve excellent agreement between different simulations for a very large array of antennas using different commercial electromagnetic simulation tools. The simulations took almost a year and close to 20,000 hours of computing to complete.

The simulated beam patterns were then verified with the help of a drone following the initial roll-out of the array, in collaboration with the National Research Council of Italy and the University of Malta (see our previous article in Contact 1).

The team is now working to determine whether the variation in element patterns will allow sufficiently accurate and rapid station-level calibration for SKA-Low.

"The next steps are to take all the data we've collected and progress the commissioning of the instrument, including making some observations," said Professor Davidson.

"We will also direct efforts towards a more suitable design maturation for the industrial production phases, as well as the (...) integration of the other parts of the telescope that are in the competence of various working packages such as Telescope Management, Central Signal Processor, Signal and Data Transport, etc.," said Jader Monari, SKA-Low Italian Programme Manager.

And so the challenge continues!

Watch the video summarising the work that's been happening and visit our Youtube channel for interviews with the team.

Completed AAVS2.0 station from overhead. Credit: ICRAR-Curtin University

DID YOU KNOW?

The full station uses 256 SKALA4.1-AL prototype antennas realised by INAF with the Italian industrial partner Sirio Antenne, a design that has successfully passed the SKA System Critical Design Review (CDR). The dual-polarised log-periodic antenna concept which ensures a broad bandwidth have been investigated and progressed as part of the design effort of the Dutch-led Low-Frequency Aperture Array Consortium (LFAA) and in particular of the Antenna & LNA working group led by the University of Cambridge. A collaboration of the University of Cambridge and INAF enhanced the dual-polarised log-periodic antenna design (SKALA4) to further improve both the performance and mechanical aspects of the design. The antenna prototype SKALA4.1-AL used in AAVS2 is showing promising results that increase the confidence that the SKA-Low challenging requirements can be met.

EU-FUNDED PROJECT SUPPORTS THE SKA

SOURCE: EU COMMISSION

AENEAS (Advanced European Network of E-infrastructures for Astronomy with the SKA) refers to a three-year initiative funded by the European Commission to support the astronomical community in the SKA era. Here's an overview of the project following its successful conclusion.

AENEAS has been funded by Horizon 2020, the research and innovation programme of the European Union. The project ran from January 2017 until December 2019 and received 3 million euros of EU funding.

As the project recently ended, the Commission asked Michiel van Haarlem, the coordinator of the project and Head of the SKA Office at ASTRON in the Netherlands, to recap the achievements of AENEAS.

What was the first and primary objective of AENEAS?

The main goal of the AENEAS project was to produce a preliminary design of the network of SKA Regional Centres (SRCs) that we must build in order to be ready for the data stream generated by the telescopes once they become operational. These regional centres will be distributed around the globe and having these ready on time is critical to getting the eagerly awaited scientific results emerging from tests of Einstein's theory of relativity and studying the signals from the first stars and galaxies that formed after the Big Bang -among many other science projects.

We investigated many different aspects of the design of the regional centres: not just the computing, data storage and networking requirements and solutions, but also the governance questions on how to organise, fund and set-up this collaboration which will involve many partners. Dealing with the unprecedented data volumes generated by the SKA is also likely to bring about changes in the way astronomers work, so we also studied how users can interact with the data and how we can prepare them for these changes.

What are the concrete benefits and impacts of the project for the scientific and research community?

The AENEAS project has made significant progress on many fronts. It has brought together the organisations that will be involved in developing and ultimately running the regional centres – not just in Europe, but also globally. The technical work packages have identified solutions (in software and in hardware) that will be adopted and further developed. We now also have a better idea of the costs involved in transporting, storing and processing the data, as well as the personnel costs of supporting users and running the network of regional centres.

By engaging with funding agencies and national observatories we have also been able to discuss important organisational and governance aspects. We have benefited from the experience gained by other pan-European projects, in particular the Worldwide Large Hadron Collider Computing Grid (WLCG) which is a global collaboration that provides computing resources for CERN's Large Hadron Collider (LHC) and the ALMA (Atacama Large Millimeter/submillimeter Array) Regional Centres that support users of the ALMA telescope in Chile. There are clear benefits to having compute and data intensive projects collaborate and share both physical resources as well as expertise and software tools.

What's next for European countries involved in SKA after AENEAS?

The SKA project is a global collaboration, so work on preparing and developing the SRC concept is also underway around the world. However, AENEAS was the first dedicated project and has led the way in exploring the full range of issues to be solved. This has increased its impact significantly. The EU funding for AENEAS has helped European countries that were interested but not yet members, to join the SKA. Many of the AENEAS partners are now also involved in the Horizon 2020 project ESCAPE, one of the European Open Science Cloud (EOSC) Cluster projects. ESCAPE brings together large research infrastructures in the fields of astronomy, particle physics and astro-particle physics, which opens up fascinating opportunities for multi-messenger discoveries with telescopes that detect electromagnetic radiation, gravitational waves, neutrinos and cosmic rays.

THE ORIGIN OF DARKNESS AND THE MOON

On 18 May, museums and art enthusiasts around the world marked International Museum Day, which this year focused on celebrating diverse perspectives. The SKA's indigenous astronomy art exhibition Shared Sky couldn't be a better match, especially since SKAO recently made the entire collection available online, following the lead of museums and art galleries internationally during the lockdown.

Curated by the SKA, Shared Sky brings together Aboriginal Australian and South African artists in a collaborative exhibition celebrating humanity's ancient cultural wisdom. Indeed, the movement of objects across the night sky has been a profound source of inspiration for artists since time immemorial. The desire to understand has informed myths and stories amongst human populations across the globe for countless generations.

In South Africa, artists we've engaged with are descendants of /Xam speaking San people living in the central Karoo region – close to the telescope site. Using textile as raw material, they produce collaborative artworks that explore their own creation myths and celebrate the ancient culture of their ancestors that survived in the harsh environment of the Karoo for millennia. This particular artwork depicts the Origin of Darkness and the Moon. Here it is in their own words:

> "The /Xam trickster, whose name was |kaggen, created from his son-in-law's shoe a tiny live Eland. He kept it hidden in the reeds, and fed it on wild honey. The Meercats, jealous and ruthless, found the Eland when it had grown large and beautiful. At once they slaughtered it and roasted it to feast on. This was the first time humanity killed for food. |kaggen, heartbroken, tried to fight them, but was losing the battle. On a bush he found his Eland's gall bladder, and in his grief, pierced it, unleashing darkness into the world. Then he threw his shoe into the sky where it became the shining moon, lighting the dark for him to fly away home."
>
> © Jeni Couzyn, 2014

"The Origin of Darkness and the Moon" – Collaborative art quilt by First People Artists, Bethesda Arts Centre: Jeni Couzyn (artistic director). Sandra Sweers (lead artist), Naas/ey Swiers, Maria Tamana, Yvonne Merrington, Gerald Mei, Riaan Swiers, Julia Ma/gas, Rentia Davidson, Felicity Tromp, Merlyn Davidson, Esmerelda Tromp, Frendoline Ma/gas, Serafine Tromp. © Bethesda Foundation. All rights reserved.

LET'S TALK ABOUT...
COSMIC MAGNETISM

BY CASSANDRA CAVALLARO (SKAO)

When you think about magnetism, your mind may return to school physics lessons, playing around with little magnets and iron filings. While magnetism is apparent to us at those very small scales, it also pervades the entire Universe.

As one of the four fundamental forces of physics like gravity, it helps to govern everything around us on Earth. Our own magnetic field, the magnetosphere, acts like a protective blanket to shield us from harmful radiation from the Sun. The beautiful auroras that we see in the skies of both hemispheres are the result of this interaction – and these auroras have been spotted beyond Earth, too. We'll come back to that later in the article.

"Magnetic fields are everywhere!" says Dr George Heald of CSIRO Astronomy and Space Science, co-chair of the SKA's Cosmic Magnetism Science Working Group. "Their influence can be felt in the space between objects, like at home when you feel the fridge door attracting a magnet before they are touching. When we talk about 'magnetic fields', it is a way to describe the ability for magnetic forces to influence objects or even light."

Let's start with the basics. Magnetic fields are generated whenever a charged particle like an electron or a proton moves, and space is full of moving charged particles – hence cosmic magnetism.

"As far as we can tell, everything in the Universe is magnetic, or at least co-exists with magnetic fields," George explains. "One of the big outstanding questions in astronomy is why magnetic fields are so strong and so organised across wide areas in space, especially inside objects like galaxies."

That strength is particularly extreme around the cores of dead stars (neutron stars or pulsars); we're talking trillions of times stronger than on Earth. But that's not the case everywhere. Vast regions between galaxies that we might think of as "empty" space still have magnetic fields, but here they may be a billion times weaker than on Earth.

"The study of magnetic fields in all these different environments is of paramount importance to track the full history of how magnetism has evolved in the Universe," says Dr Valentina Vacca of INAF, co-chair of the working group alongside George. "Magnetic fields in evolved systems, like planets, stars, galaxies and clusters of galaxies, reflect this evolution, while those in more diluted environments such as filaments and voids between clusters of galaxies can give us precious information about more 'pristine' magnetic fields."

While there's much we don't yet understand about magnetism's role in the Universe, we know that it influences star formation, affecting how many stars are created from gas clouds inside galaxies, and how massive they become. It's also possible magnetic fields affect the evolution of galaxies, for example influencing the formation of the arms of spiral galaxies.

Of course, we can't see magnetic fields, so how do we study them?

"The only way we have to see them is through their actions," says Valentina. "There are three physical mechanisms we can observe at radio wavelengths, so radio telescopes allow us to study magnetic fields with great detail compared to other telescopes."

Spiral galaxy NGC 628, around 32 million light years from Earth in the constellation Pisces. The flow lines overlaid on this optical image trace the orientation of the magnetic fields that run through the disk of this galaxy, as traced by radio observations. Credits: Optical image: Steve Mazlin and Vicent Peris, Calar Alto Observatory; Radio data: Mulcahy et al. 2017, Jansky Very Large Array (VLA)

Time to get technical. The first mechanism is known as "Faraday rotation", named for 19th Century British scientist Michael Faraday. Radio telescopes are highly sensitive to what we call polarised radiation – radio waves emitted by a distant object which travel to us along a single plane, rather than in lots of different directions.

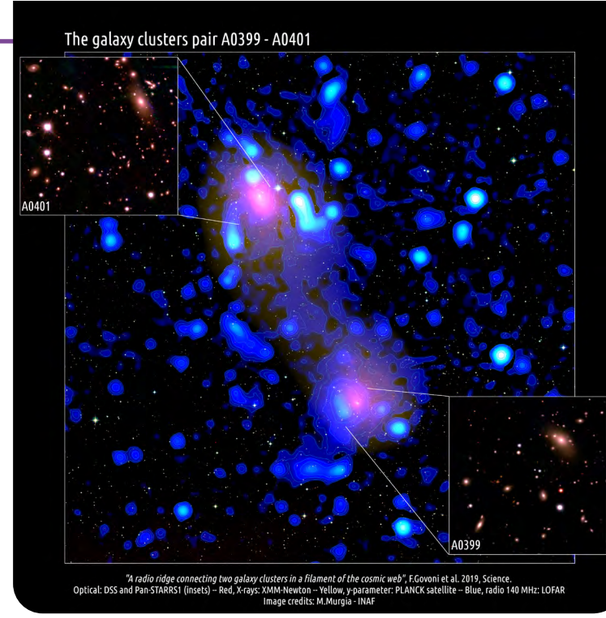
On their way to Earth, the waves can be "twisted" by the magnetic fields of other objects they encounter, a change that radio astronomers can detect and use to measure the magnetic environment of those objects in between.

Next, we have "Zeeman splitting", named after Dutch physicist Pieter Zeeman, who shared the 1902 Nobel Prize for his discovery. Here the narrow emission lines produced by atoms and molecules are split by the effects of magnetic fields. Emission lines are like the fingerprints of astronomical objects. When these lines split, it signals a change in energy that astronomers can observe, and enables them to measure the strength of the magnetic fields.

The third mechanism radio astronomers can observe is called synchrotron emission, a type of radiation generated by charged particles spiralling around magnetic field lines at close to the speed of light. That's been at the heart of two recent discoveries involving the MeerKAT (see page 26) and LOFAR radio telescopes.

With LOFAR, researchers detected emission from a star which had the tell-tale signature of auroras, meaning it was likely being created by an interaction with an orbiting planet (Read our previous article on this story). In other words, the effects of magnetism had potentially opened up a new way of detecting exoplanets. Until now, exoplanet discoveries mostly involved using an optical telescope to measure the dip in a star's light as its orbiting planet passed by, or the star's "gravitational wobble" caused by the planet's orbit, George explains.

"The radio technique can not only help us to understand the environment, including the magnetic field, around known exoplanets, but can possibly help us to find new exoplanets that are too small or far from their parent star to cause much of a gravitational wobble," he says.



Cosmic magnetism, exoplanets and distant galaxies might all seem a bit disconnected from everyday life in these strange times for world health, but important crossovers do occur.

"The signals used to study cosmic magnetism and other phenomena are often very faint from distant objects which require sensitive and high resolution images, a bit like the difficulty doctors have when trying to image parts of the human body," Valentina notes. "In radio astronomy, techniques such as aperture synthesis – simulating a very large antenna with a collection of small ones – have been developed to tackle this, and medical imaging uses a technology inspired by it."

The newest generation of radio telescopes, in particular SKA pathfinders and precursors like LOFAR, MWA, ASKAP, and MeerKAT, are especially well-suited to studying cosmic magnetism thanks to the broad range of frequencies they cover and high sensitivity, two key things you need to study faint and distant objects. The SKA will provide another leap in capabilities, allowing astronomers to map the vast magnetic structure which connects the Universe on the grandest scales.

"We want to trace the beautiful 'cosmic web' that stretches through space on scales of tens and hundreds of millions of light years and more, and within which clusters of galaxies are embedded," George says. "The SKA will enable us to study the magnetic fields in cosmic objects to a level of detail that we have been unable to achieve with any other radio telescope so far. We hope to reveal where magnetic fields originally came from, and how they've shaped our Universe!"

Above: Here the radio emission is shown in blue; the diffuse emission along the filament connecting the two clusters is a direct expression of the magnetic field permeating this region.

> **"THE SKA WILL ENABLE US TO STUDY THE MAGNETIC FIELDS IN COSMIC OBJECTS TO A LEVEL OF DETAIL THAT WE HAVE BEEN UNABLE TO ACHIEVE WITH ANY OTHER RADIO TELESCOPE SO FAR."**
>
> Dr George Heald, CSIRO Astronomy and Space Science

DID YOU KNOW?

The technique of combining signals to create one image, used in radio astronomy interferometers such as the SKA, is also behind Magnetic Resonance Imaging (MRI) scanners, enabling doctors to get a clear picture of the inside of the human body.

2 MINUTES WITH...
DAVID BRIGGS
LORD-LIEUTENANT OF CHESHIRE

Early March, SKA HQ was getting ready to host its first head of state, Her Majesty Queen Elizabeth II, when the visit had to be postponed due to the coronavirus pandemic. As Lord-Lieutenant of Cheshire, the county where SKA HQ is located, David Briggs played a key role in preparing the visit. We spoke to him about his work.


Credit: David Briggs

Tell us about what your role involves.

There is a Lord-Lieutenant in each county of the UK, who is the Queen's representative and helps to organise royal visits among other things. I've been in this role for 10 years, and I was very involved in planning a visit of Her Majesty to the SKA HQ, which sadly had to be postponed because of the coronavirus. Each visit is meticulously planned, every minute is carefully considered to make sure the Queen meets all the people she ought to meet, and to coordinate with media and security services.

About 80% of my time is spent on community work and supporting local charities, including fundraising for those helping people during the current COVID-19 situation. My team of 43 deputies has also been finding ways to help National Health Service workers, such as sourcing fresh food and hand sanitiser, and making a counsellor available.

What did the preparations for the visit focus on?

It was about talking to the management of SKA to ensure the very most can be made of a relatively short visit. At least three months of preparation goes into such a visit to cover all the different elements, from policing to catering requirements and many other logistical details.

I was particularly keen for the Queen to visit the HQ because with Australia, South Africa and the UK as host countries, this is an extraordinary, exciting initiative involving Commonwealth members. Given the Queen is very passionate about the Commonwealth, I thought she would be very interested to see how they've been working together on what I describe as the "world's biggest science project". The plan is very much to reschedule the visit, although of course we can't know a date yet.

What was your impression of the HQ as a home for the SKA, and in terms of what it means for the local area?

When I first visited my reaction was "wow". It is so exciting – many people think of Cheshire as agricultural, but the SKA's arrival makes people realise that the county is also a centre of world scientific expertise. I spend a lot of time speaking to schoolchildren and explaining why it's so important to study STEM subjects at school, and showing them that there are so many opportunities to have fascinating careers in science and technology. Having the SKA HQ here is really helpful in selling Cheshire as a home for budding new scientists.

MOVING TO **A NEW REALITY**

The first mention of coronavirus in an all-staff email at SKAO was on 28 January. Since then, the SKA HQ has gradually implemented a series of measures to adapt to the COVID-19 pandemic and since mid-March, in line with the UK government recommendations, SKAO has been operating remotely.

The IT tools needed for a global project to function - in our case Confluence, Zoom and Slack - have allowed us to adapt quickly, and while they were previously only used by some teams, they've now been adopted by almost everyone as de facto communications channels.

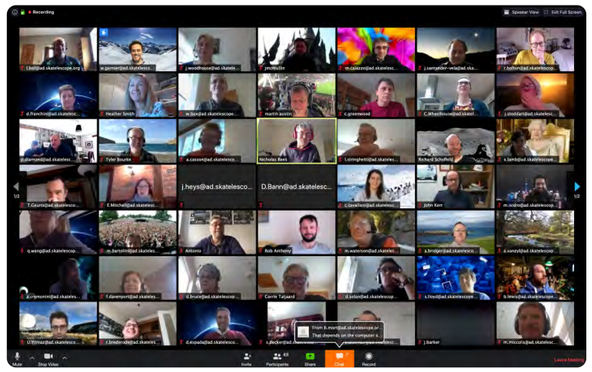
A weekly internal newsletter was launched to provide relevant information but also to keep everyone feeling informed and connected and avoid the all-too-easy trap of working in silos that can come with remote-working.

And at a time when many companies have frozen hires, SKAO has continued hiring new staff critical to the delivery of the plan, with interviews, panels and on-boarding being conducted remotely, and new staff working from home, including abroad. A buddy system is now in place, connecting our new hires with colleagues outside their teams, to help create that sense of belonging, despite not having set foot in the office yet.

Highlights of the office life have continued online, providing a constant in our lives, like the weekly all-hands coffee update by the DG. Perhaps equally important is the weekly (virtual) pub outing that has become even more inclusive, with spouses and partners joining in for an opportunity to catch up. There's only one rule: no work discussions!

The SKAO Family Facebook group has also come into its own, providing a means for staff and their families to share useful resources about online activities, schooling, etc.

Of course, adapting to this new routine comes with challenges. New words like 'meetingitis' and 'zoombified' have been coined, and home-schooling or caring responsibilities can take their toll, especially when an already heavy workload and tight deadlines haven't gone away. A particular emphasis has been put on mental health to support staff in getting their work-life balance right, with a number of appreciated initiatives implemented around Mental Health Awareness Week. Overall, SKAO staff have proved extremely resilient in the face of adversity, and continue to adapt to keep the project moving forward together with international colleagues. So to borrow from our Italian friends, *andrà tutto bene.*



MEET THE TEAM: **LEGAL**

Among a wide variety of expertise at SKA HQ is a team of legal specialists. They make sure we remain compliant with the laws and regulations of different jurisdictions and over the past few years have been applying their skills to the complex transition of SKA Organisation towards becoming an Inter-Governmental Organisation (IGO), among many other things. Let's meet the team!

In-House Legal Counsel Theunis Kotze from South Africa is an international law expert. Theunis has decades of experience in criminal, intellectual property, competition and international law. He joined the SKA Organisation from the South African Foreign Affairs Department, where he provided training in international law to fledgling diplomats and advised South African delegations to the African Union, World Intellectual Property Organisation, International Telecommunications Union, and United Nations' Committee On the Peaceful Uses of Outer Space among many others. While at SKAO, Theunis has been instrumental in facilitating the legal process behind establishing the SKA Observatory IGO Convention and the UK Headquarters Agreement, from negotiations to drafting of the treaties to signature and ratification.

"A multilateral project of this magnitude, with so many countries collaborating, requires on the one hand a lot of diplomacy, but also a great attention to legal details – to the nitty gritty of legislation in all our member countries and beyond. There is always something weird, exciting and unexpected in my inbox," Theunis explains.

Indeed, the team works across many different areas of law; from international law and intellectual property to varying labour laws around the world. They're constantly liaising with legal firms in the SKA's host countries to advise on changes in legislation and their implications on the SKA.

That's why having an in-house team who speak the same (notoriously tricky) legal language – and know which questions need to be asked when – is essential.

Assistant In-House Legal Counsel Shelley Decker is an English-qualified solicitor. She previously worked for UK Research and Innovation (UKRI), supporting the UK membership of international science infrastructure projects such as CTA, XFEL, FAIR & LIGO. Shelley's primary focus at SKAO is advising on English law matters, such as queries concerning employment law, company law, property and intellectual property. A sizable portion of Shelley's time involves drafting and negotiating a variety of contracts, both for the future IGO (such as the Host Country Agreements with South Africa and Australia) and for the current company. Shelley also drafts MoUs to strengthen working relationships with other organisations, such as the MoU signed with the CTA Observatory recently.

"Because of the collaborative nature of our work, we have many relationships with other organisations, which means dozens of agreements," explains Shelley "so we will be quite busy ensuring that all of these are properly transferred from the current company to the IGO!"

Legal Advisor for Transition and Change Betty Kioko from Kenya initially joined as a graduate intern working on the legal scrub – checking the consistency of legal language – of the SKA Observatory Convention. She brought with her experience from a corporate law firm in Nairobi and a Master of Laws in International Law degree from the University of Manchester. She points out that the SKA Observatory will be groundbreaking not just scientifically, but also legally.

"A transition from an English company to a UK-headquartered IGO has not been done before, so we are writing the rule book and setting some precedent on how to do this," says Betty.

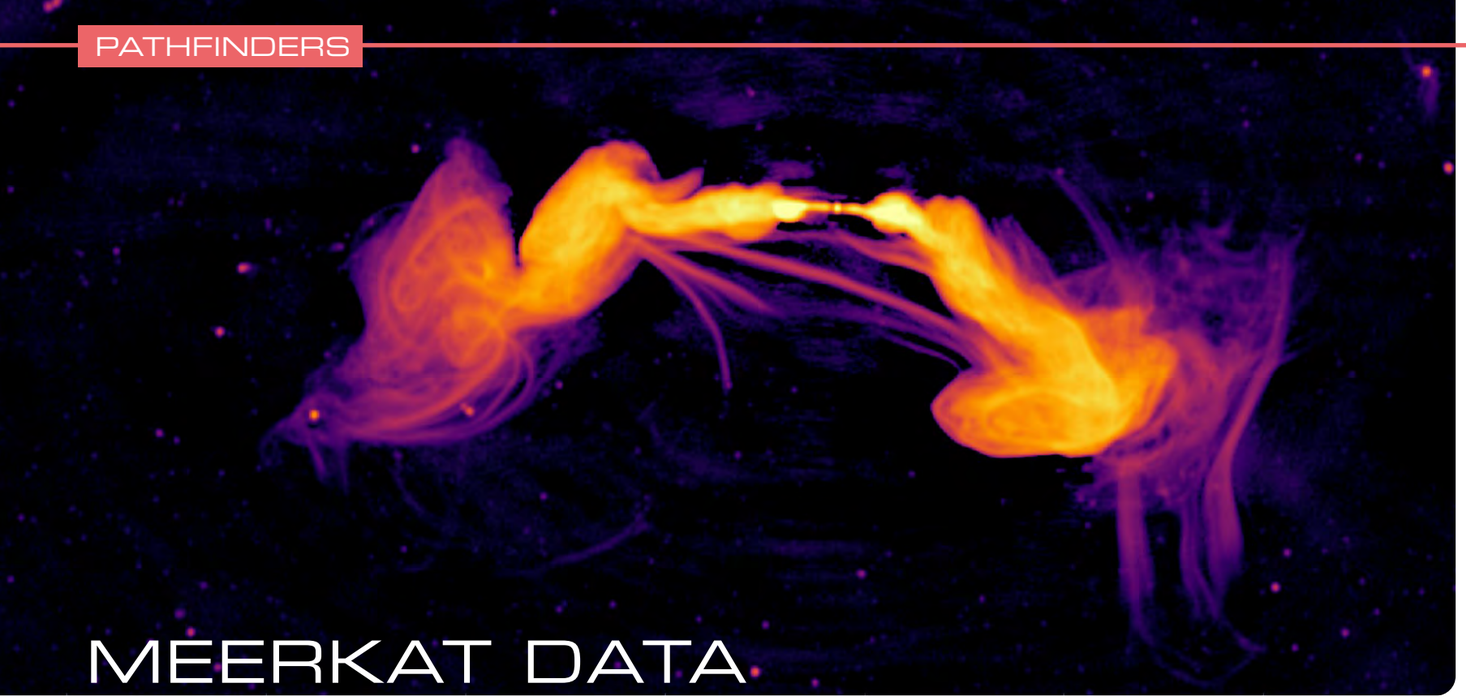
SKAO's Legal Team was present at the signature of the SKA Observatory Convention in Rome in March 2019. Pictured here are Assistant In-House Legal Counsel Shelley Decker and Legal Advisor Betty Kioko.

"Behind it all, it's about our people, and the implications the transition process may have on their lives. It's very complex and requires regular interaction with the UK government's experts to understand all the ramifications because each person's situation is different and unique."

Like many, they've been adjusting to homeworking during the COVID-19 pandemic and the shutdown of the SKA HQ, but are also confident about the future.

"It is a difficult time globally, so it has been heartening to hear positive messages from governments about their support for the SKA," says Betty. "We're staying optimistic about emerging from the pandemic, and that includes looking forward to more ratifications of the Convention, and the beginning of the SKA Observatory."

SKA In-House Legal Counsel Theunis Kotze (right) welcoming then South African Science Minister Ms Mmamoloko Kubayi-Ngubane at the SKA Headquarters following the signature of the SKA Observatory Convention. Credit: Department of Science & Innovation



MEERKAT DATA **REVEALS UNEXPECTED FEATURES** IN DISTANT GALAXY

BY SARAO

An international team of astronomers has uncovered unusual features in a radio galaxy using data from South Africa's MeerKAT telescope, a precursor to the SKA.

The radio galaxy resides in a galaxy cluster located around 222 million light years from Earth, and is one of the brightest objects in the southern sky at radio wavelengths. The classical picture of a radio galaxy consists of an active galactic nucleus that hosts a growing supermassive black hole, shooting out two jets of plasma filled with particles that move at speeds close to the speed of light. The material within the jets eventually slows down and billows out, forming large radio lobes.

The galaxy in question is characterised by two such lobes of very bright radio emission, but, unexpectedly, the new observations with MeerKAT show multiple previously unseen parallel threads of radio emission connecting the two lobes which are thought to be caused by synchrotron radiation, explains Dr Mpati Ramatsoku, a Research Fellow at Rhodes University and lead author of the study.

The nature of these unusual features is unclear; they may be unique to the galaxy because of its harsh environment, or could be common in radio galaxies but, so far, we have been unable to detect them due to instrument limitations. Dr Ramatsoku adds that understanding the nature and the physics of these threads could open a new science case for sensitive radio interferometers like MeerKAT and, in the future, the SKA. "Such serendipitous discoveries are very important for MeerKAT because it highlights its incredible capacity for finding the 'unknown unknowns' in our Universe," said Prof. Oleg Smirnov, Head of the Radio Astronomy Research Group at SARAO. Read more on the SARAO website.

Above: Image reconstructed using radio emission data from MeerKAT at 1000 MHz, showing unusual parallel threads connecting radio emission lobes of the galaxy (M. Ramatsoku et al., 2020, A&A). Credit: Rhodes University/INAF/SARAO

> **"SUCH SERENDIPITOUS DISCOVERIES ARE VERY IMPORTANT FOR MEERKAT BECAUSE IT HIGHLIGHTS ITS INCREDIBLE CAPACITY FOR FINDING THE 'UNKNOWN UNKNOWNS' IN OUR UNIVERSE."**
>
> Professor Oleg Smirnov, Head of the Radio Astronomy Research Group at SARAO

MEERKAT **SOLVES MYSTERY OF X-SHAPED GALAXIES**

BY SARAO

A team of astronomers from South Africa and the US have used the MeerKAT telescope, an SKA precursor facility, to solve a longstanding puzzle in 'X'-shaped radio galaxies.

Many galaxies far more active than the Milky Way have enormous twin jets of radio waves extending far into intergalactic space. Normally these go in opposite directions, coming from a massive black hole at the centre of the galaxy. However, a few are more complicated and appear to have four jets forming an 'X' on the sky.

Several possible explanations have been proposed to understand this phenomenon. These include changes in the direction of spin of the black hole at the centre of the galaxy, and associated jets, over millions of years; two black holes each associated with a pair of jets; and material falling back into the galaxy being deflected into different directions forming the other two arms of the 'X'.

Exquisite new MeerKAT observations of one such galaxy, PKS 2014-55, strongly favour the latter explanation as they show material "turning the corner" as it flows back towards the host galaxy.

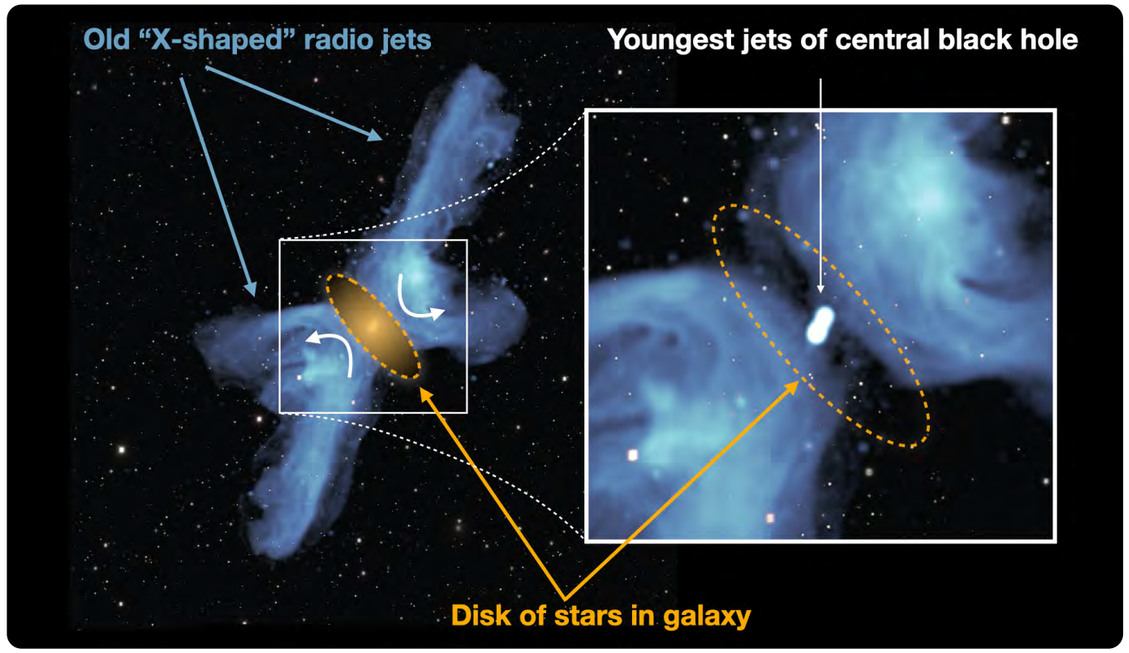
This work was carried out by a team from the South African Radio Astronomy Observatory (SARAO), the (US) National Radio Astronomy Observatory (NRAO), the University of Pretoria and Rhodes University in South Africa.

The team's paper was published in the Monthly Notices of the Royal Astronomical Society.

Previous studies of these unusual galaxies lacked the high quality imaging provided by the recently completed MeerKAT telescope. Computers combined the data from the MeerKAT antennas into a telescope 8 km in diameter, and provided images in the radio band of unprecedented quality for PKS 2014-55, which enabled solving the mystery of its shape.

Further research into these open questions is already underway. Read more on the SARAO website.

Below: Annotated image showing X-shaped giant radio galaxy PKS 2014-55, observed with the South African Radio Astronomy Observatory's MeerKAT telescope, indicating the old X-shaped radio jets, the younger jets closer to the central black hole, and the region of influence dominated by the central galaxy's stars and gas. The curved arrows denote the direction of the backflow that forms the horizontal components of the X. Credit: UP; NRAO/AUI/NSF; SARAO; DES.



FAST TELESCOPE TURNS TO **OPERATIONS FROM CONSTRUCTION**

BY F. F. KOU & BO PENG (CHINESE ACADEMY OF SCIENCES KEY LABORATORY OF FAST, NAOC)

FAST, China's mind-blowing 500-metre diameter SKA Pathfinder telescope, formally switched to operations earlier this year after completing its national acceptance on 11 January 2020, when all technical specifications met the design baseline. Since its construction was completed in September 2016, the world's largest single dish radio telescope has undergone a thorough technology verification and system performance check.

Over the past three years, FAST successfully implemented various observing modes and made remarkable early science achievements, especially in the field of pulsar science. In August 2017, FAST discovered its first pulsar, and has since discovered more than 110 new ones. In February 2018, it detected its first millisecond pulsar, which coincides with a previously unassociated gamma-ray source observed by NASA's Fermi space telescope. The discovery of this extremely faint pulsar demonstrated FAST's great potential for pulsar searching. In February 2020, FAST announced the discovery of a new binary millisecond pulsar in the globular cluster M13, confirmed one of the previously identified pulsars in the cluster was a 'black widow' binary – a type of millisecond pulsar that 'eats' its companion star while orbiting it – and then went on to measure the timing of all known pulsars in M13 with the highest precision to date. Soon afterwards, FAST found a 'redback' pulsar – a similar type of millisecond pulsar – in the globular cluster M92; the first binary pulsar to be observed there. The discovery of binary pulsars is the third milestone FAST achieved in pulsar research.

The facility's key science projects have now started, including surveys such as the Commensal Radio Astronomy FAST Survey and the Galactic plane pulsar survey; but also projects undertaking Fast Radio Burst (FRB) research, neutral hydrogen imaging, pulsar searching in M31 and pulsar timing.

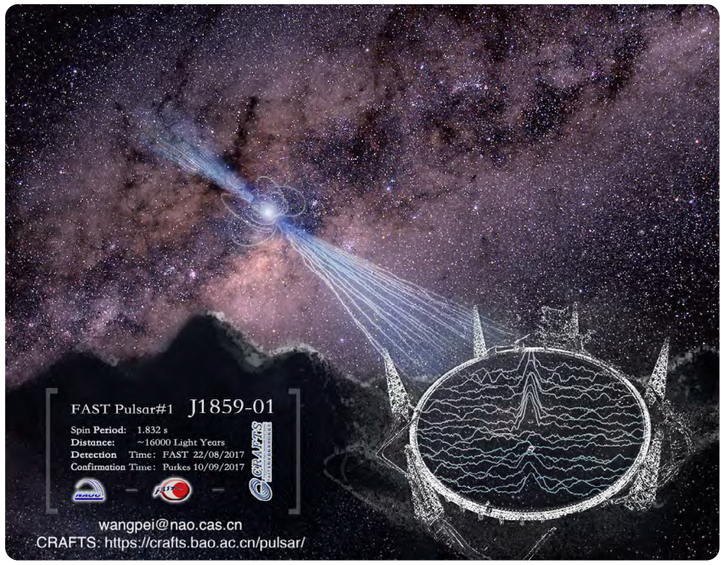
Individual Principal Investigator-led proposals will open for Chinese users this summer, and in a year's time for international users.

FAST has already shown its unique sensitivity in all related scientific research. Observations of three rotating radio transients with FAST revealed their pulses are more frequent than previously observed. In the future, the giant telesccope is also expected to contribute to frontier research, such as the detection of gravitational waves and new FRBs as well as observing interstellar molecules.

You can read more about the science and technology behind FAST in a special topic of Science China here.

Left: A Special issue of Science China covering FAST early Science. Credit: Science China

Below: The first pulsar discovered by FAST in 2017. Credit: NAOC



ASTRONOMERS DISCOVER **NEW CLASS OF COSMIC EXPLOSIONS**

SOURCE: NRAO

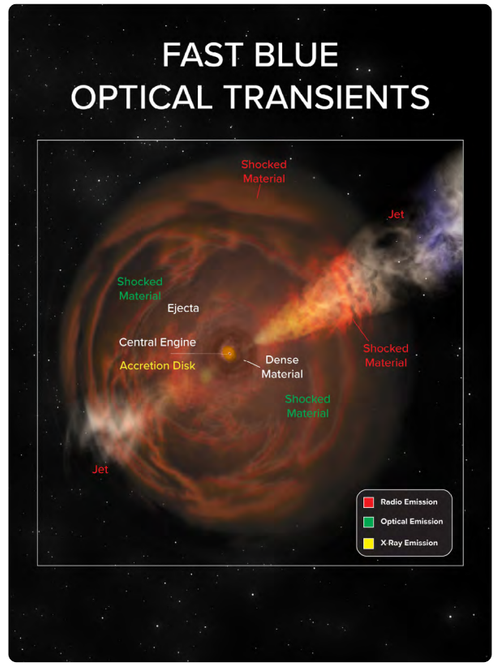
Using a range of telescopes operating at different wavelengths, astronomers have found three separate objects that constitute a new class of cosmic explosions, in papers published in the Astrophysical Journal and the Astrophysical Journal Letters.

The astronomers followed up on these objects first discovered using optical telescopes by observing them with two SKA pathfinders: the NSF's Very Large Array in the US and NCRA's Giant Metrewave Radio Telescope in India, as well as NASA's Chandra X-ray space telescope.

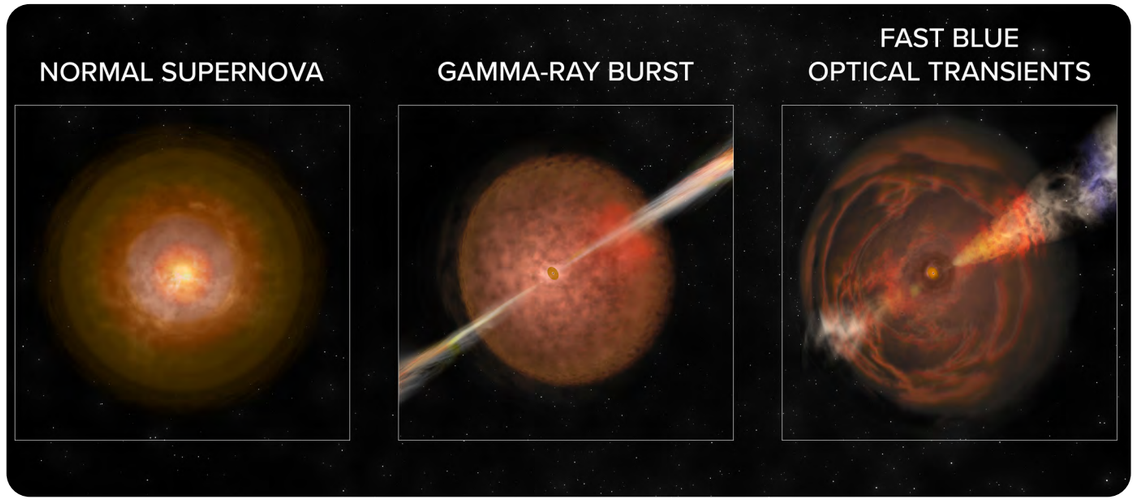
These so-called Fast Blue Optical Transients (FBOTs) probably begin the same way as certain supernovae and gamma-ray bursts – when a star much more massive than the Sun explodes at the end of its "normal" atomic fusion-powered life.

However, FBOTs seem to be enshrouded by thick material that was probably shed by the star just before it exploded. When the thick material is struck by the blast wave of the explosion, it causes a bright visible-light burst. And as the blast wave collides with the material around the star as it travels outwards, it produces radio emission.

The astronomers also found that all three objects are located in small, dwarf galaxies, which leads them to believe that the dwarf galaxy properties might allow some very rare evolutionary paths of stars that lead to these distinctive explosions. To better understand this new class of cosmic explosions, they hope to observe more FBOTs and their environments using telescopes covering a wide range of wavelengths.



Artist's conception illustrates the phenomena that make up the new class of cosmic explosions called Fast Blue Optical Transients. Credit: Bill Saxton, NRAO/AUI/NSF



The artist's conception illustrates the differences in phenomena resulting from an "ordinary" core-collapse supernova explosion, an explosion creating a gamma-ray burst, and one creating a Fast Blue Optical Transient. Credit: Bill Saxton, NRAO/AUI/NSF

ASKAP HELPS TO UNVEIL UNIVERSE'S MISSING MATTER

BY ICRAR AND CSIRO

Astronomers have used Fast Radio Bursts (FRBs) to detect "missing matter" -not to be confused with dark matter-, long predicted to exist in the Universe and hinted at in previous measurements but never detected - until now. The researchers detected missing "normal" matter in the vast space between stars and galaxies. Their findings are reported in the journal Nature.

Lead author Associate Professor Jean-Pierre Macquart, from the Curtin University node of the International Centre for Radio Astronomy Research (ICRAR), said astronomers have been searching for the missing matter for almost 30 years.

"We know from measurements of the Big Bang how much matter there was in the beginning of the Universe, but when we looked out into the present Universe, we couldn't find half of what should be there."

They thought the matter should be out there, but couldn't detect it. That posed a problem – how do you prove something is present when you can't see it?

The researchers were able to directly detect the missing matter using fast radio bursts which they detected and then localised to their origins using CSIRO's Australian Square Kilometre Array Pathfinder (ASKAP) radio telescope.

This was accomplished by first measuring the delay between the wavelengths of an FRB using ASKAP, and then calculating the distance of the FRB from Earth. The delay between wavelengths signals the presence of matter, and can be used to work out its density as long as you have the distance from Earth.

A whole network of FRBs was used in the study, acting as "cosmic weigh stations".

Dr Keith Bannister from CSIRO, Australia's national science agency, who designed the pulse capture system used in the research, said that when fast radio bursts arrive at the telescope, ASKAP records a "live action replay" within a fraction of a second.

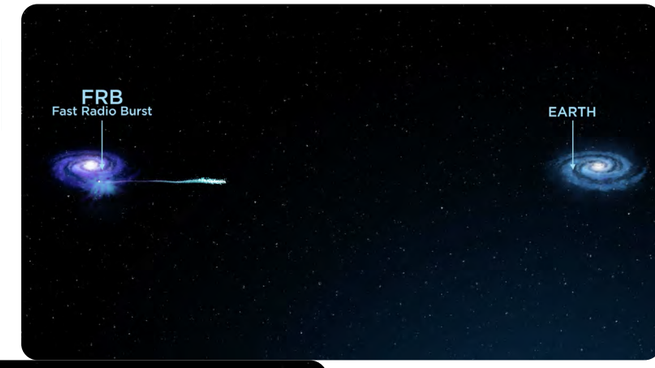
"This enables the precision to determine the location of the fast radio burst to the width of a human hair held 200m away," he said.

Associate Professor Macquart said this result underscores the strong connection between instrument design and science.

"ASKAP's success is just like Formula 1, no driver can win a championship without the backing of a whole team of engineers and mechanics," he said.

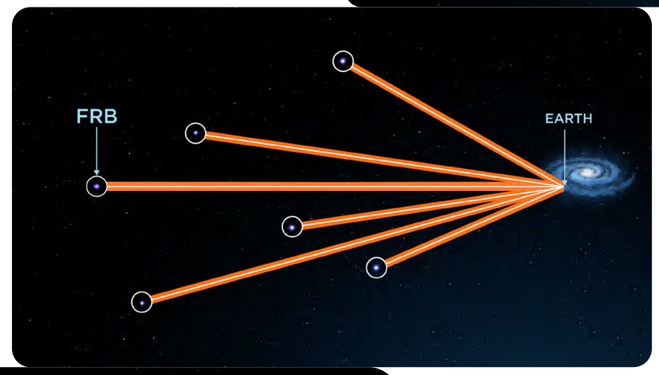
"The team working on FRBs with ASKAP is a tight-knit collaboration – it harnesses expertise spanning five continents that exploits the best the world has to offer in terms of radio, optical, simulation and theory."

> **"ASKAP'S SUCCESS IS JUST LIKE FORMULA 1, NO DRIVER CAN WIN A CHAMPIONSHIP WITHOUT THE BACKING OF A WHOLE TEAM OF ENGINEERS AND MECHANICS."**
>
> Associate Professor Jean-Pierre Macquart
> ICRAR-Curtin

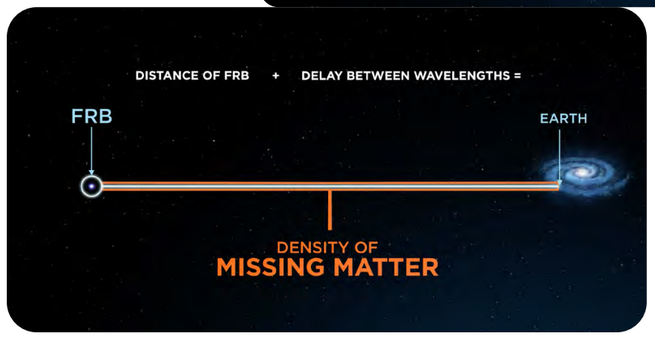


The FRB travels from its host galaxy to Earth. Credit: ICRAR

The FRB leaves its host galaxy as a bright burst of radio waves. Credit: ICRAR

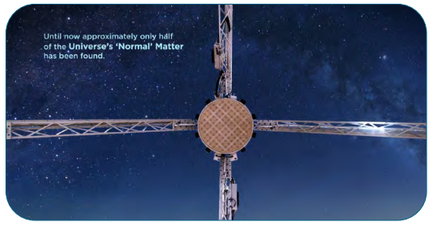


A network of FRBs was used to measure the density of the missing matter. Credit: ICRAR



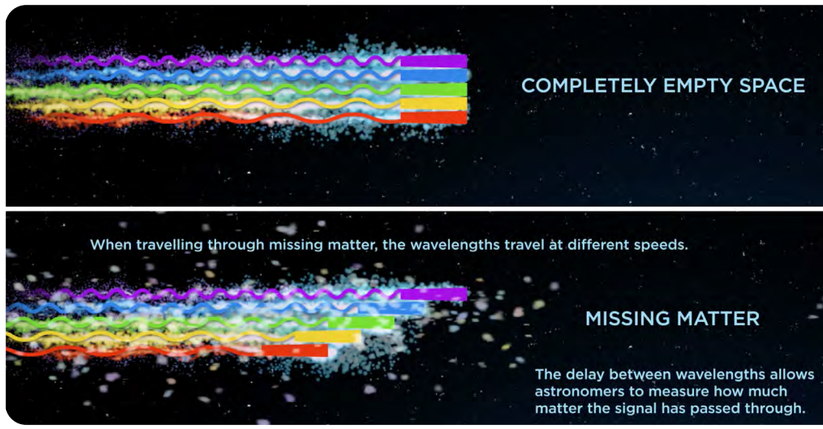
The density of missing matter is calculated using the distance of the FRB from Earth, and the delay between the wavelengths of the FRB as detected by ASKAP. Credit: ICRAR

Watch the video.



DID YOU KNOW?

The Universe is believed to be made up of dark energy, dark matter and "normal matter" – the latter being everything we can see, Earth, planets, stars, etc. The best available current models estimate dark energy to represent about 68% of the universe, dark matter 27% and normal matter only 5%. But "normal matter" also has its own invisibility problem and of that 5%, we can only see about half of it.



When travelling through completely empty space, all wavelengths of the FRB travel at the same speed, but when travelling through the missing matter, some wavelengths are slowed down. Credit: ICRAR

NATHANEAL MORGAN

Mechanical engineer Nathaneal Morgan joined the South African Radio Astronomy Observatory (SARAO) straight out of university. Having been part of the SKA's Infrastructure South Africa design consortium, where he worked on the heating and cooling requirements for the sensitive equipment on site, Nathaneal is now based in Cape Town and part of the SARAO-led National Ventilator Project (see page 11). We spoke to him about his route into engineering, what the SKA means for South Africa, and how he was inspired by the classic movie *Back to the Future*.

Let's begin with your childhood, Nathaneal – was anyone in your family involved in science or engineering?

I grew up in Johannesburg, South Africa and was the first one in my family to be able to attend university. Growing up I don't even think I knew anyone else who had attended university, never mind being involved in science or engineering. Although, my dad was always tinkering with old computers – picking them apart and building them up again. I guess that must have been my first real exposure to anything engineering related. I didn't have much interest in that at the time but was exposed to the processes and curiosity of understanding how things work.

So when did you start to take an interest in STEM?

I don't recall one particular event, but perhaps a collection of reinforcing events throughout my life. I remember watching *Back to the Future* and thinking that Marty McFly's hoverboard was the coolest thing I had ever seen and I desperately wanted one. My parents obviously couldn't get me one so I decided that I would become a scientist/inventor when I grew up, so that I could make one for myself (I haven't quite cracked it yet).

When I was 13 years old, I was asked to give a farewell speech to my classmates as we all prepared to move on to high school. My dad helped me write it and the overarching idea was something like: "I hope that this group will produce future doctors, lawyers, artists… and engineers." I remember not wanting to add that last part into the speech because I didn't actually know what an engineer did. I did some research and found the engineering-related processes of design, manufacturing, and innovation are applied across a wide range of industries and was intrigued by the possibilities. I began watching a lot of shows like *How It's Made* and *MythBusters*, which enhanced that scientific curiosity in me – naturally I gravitated towards STEM.

You joined SARAO through the young professionals programme they run – why did you choose to apply?

I had just completed my Bachelor's degree and was applying for every vacancy I could find, but remember being particularly interested in this opportunity. It was a collaborative Young Professionals Development Programme between the SKA's Infrastructure South Africa design consortium and an external engineering institute. Experienced engineers were available to offer valuable consulting services, while graduates were incorporated into the programme to gain industry experience and facilitate knowledge transfer – this appealed to me. I spent my first year at SARAO under secondment, and was offered a permanent contract thereafter.

What's your specialism at SARAO now and how does it relate to the SKA?

I am a Mechanical Engineer working primarily on the African Very Large Baseline Interferometry Network (AVN). The AVN programme helps to develop the skills and capacity needed in SKA African partner countries to encourage and optimise African participation in related development and science.

Currently, I am part of a fantastic team working on a conversion project, where an existing antenna in Ghana – previously used for telecommunications services – has been designated for conversion into a radio telescope. The change in functionality imposes a new set of requirements on the structure and control system, and I am responsible for the design, assembly, and subsequent utilisation of a Qualification Test Rig. The rig has been built at the SARAO offices in Cape Town and is being used to test the mechanical installation and integration of major components relating to the conversion, in particular to improve the positional accuracy of the antenna, which is crucial to track celestial objects.

When did you first hear about the SKA, and what made you want to be part of it?

Probably when I was applying for the graduate programme. I was amazed by the scale, technical requirements and potential impact that a project of this magnitude could have, and wanted to be part of the team that delivered it. I mean it's a ground-breaking build, the products of which could fundamentally change our understanding of the Universe, who wouldn't want to be part of something that monumental? I also felt that the international collaboration would offer unique opportunities for networking and professional exposure. I was able to meet some international colleagues from the central office as part of the Critical Design Review (CDR) visit, and I hope to be able to take advantage of similar opportunities in the future.

What does the SKA mean for you as a young South African, and for the country as a whole in your opinion?

I'm proud to be part of the project and feel like I am genuinely contributing towards something that will have a lasting impact on the global scientific community. I am part of a vastly knowledgeable and capable team, which allows me to enhance and diversify my own skills as an engineer. I think that this increased exposure to STEM and the subsequent development of human capital are critically important factors in determining the overall success of the SKA.

From an African perspective, it's important to showcase our talent and resourcefulness in being able to deliver these instruments, thereby increasing further investment opportunities in our country. The scale of this project is immense and the close collaboration between partner countries provides a perfect opportunity to highlight our capability to a global audience. The progress that we have made thus far provides concrete evidence of the quality that can be produced in Africa when we work towards a common goal. As a key stakeholder in the SKA, I think the entire country is invested in the success of this project.

Sometimes science and engineering are seen as not very diverse or inclusive. What has been your experience of this, and how do you feel it could be improved?

Although these are global issues, we as South Africans perhaps have a unique perspective on the effects of discrimination and inequality on a society. Building an inclusive industry (and society as a whole) requires purposeful commitment to transformation and diversity management, and the perseverance that comes with it; because real change can't happen overnight. Additionally, genuine diversity and inclusiveness is not a superficial tick-box exercise, but a migration towards all people respecting and valuing the inputs and perspectives of those from different backgrounds. I think the industry still needs more of this, but I have been greatly encouraged by the approach and attitude of my team at SARAO.

What advice would you give to young people who might want to follow your lead?

Be curious and stay humble. Curiosity will make it easier to find things that interest you; this is important because you will likely put more effort into something that you find appealing, and produce better results. Actively try to identify interesting aspects in every project you do and learn something new about it. There will be times (plenty of times!) when you need help, ask unashamedly and accept assistance humbly.

Let's talk about outside of the office – how do you take your mind off work?

I'm an avid sports fan and enjoy watching and playing often. I have a particular fondness for football and I spend a lot of time reading, analysing, and discussing tactics and performances particularly those related to my favourite team Manchester United. We have access to a sports field close to the SARAO offices in Cape Town where we play weekly matches after work – it's a great way to keep fit and socialise with colleagues outside of the office environment. Unfortunately, these activities have been curtailed due to the effects of the COVID-19 pandemic and subsequent lockdown measures.

I also enjoy cooking and recreating dishes I see online. Actually, I probably just like eating delicious food and cooking is simply a means to an end!

> "I FEEL LIKE I AM GENUINELY CONTRIBUTING TOWARDS SOMETHING THAT WILL HAVE A LASTING IMPACT ON THE GLOBAL SCIENTIFIC COMMUNITY."
>
> Nathaneal Morgan, SARAO

Images courtesy of Nathaneal Morgan. All rights reserved.

Team SKA

In each issue of Contact, we'll get to know one of the many talented people contributing to the SKA, hearing about their work, how they got here and their advice for the next generation.

A BRIEF RECAP OF THE BIG STORIES COVERED BY THE SKA COMMS TEAM IN RECENT MONTHS.

Since the last issue of Contact was published in early March, much has changed globally. On 17 March, SKA Global Headquarters was closed in line with guidance from the UK government on containing the COVID-19 pandemic. With the wellbeing of staff, their families and communities a priority, SKAO instructed all staff to work from home until further notice, with no domestic or international business travel to be undertaken.

A few weeks later our South African partners SARAO announced that they had been tasked with managing the national effort required for the local design, development, production and procurement of respiratory ventilators to support the government's response to combat the pandemic there. The decision recognised the significant expertise and experience engineers and scientists have gained in the development of complex systems for the MeerKAT radio telescope, an SKA precursor facility. Many of the SKA's partner institutions have been similarly involved in their respective countries – see our feature on page 11.

While the pandemic dominated many conversations and headlines, there was positive news in the SKA world with the announcement that the Swiss science and technology university École Polytechnique Fédérale de Lausanne (EPFL) had become the 14th member of the SKA Organisation. EPFL is the lead institution coordinating involvement in the SKA on behalf of the Swiss academic community.

SKA Director-General Prof. Philip Diamond also issued an update on the status of the SKA project, highlighting the progress that continues to be made despite current restrictions. "None of us can predict what the coming months will bring," he wrote, "but, as one of the world's major scientific endeavours, we hope to push forwards bringing employment, innovation and scientific exploration to benefit our partner countries."

Spotted on social media: A message from our Solar System neighbours in this difficult period.

NEWS FROM AROUND THE WEB

CAREERS WITH STEM

Meet Dr Sarah Pearce – CSIRO Astronomy and Space Science Deputy Director Sarah Pearce was recently named 2020 Telstra NSW Business Woman of the Year.

THE CONVERSATION

Technology, international bonds, and inspiration: why astronomy matters in times of crisis – Australia's Astronomer-at-Large Fred Watson on the resilience of astronomy throughout history, and the importance of the SKA.

CNN

Southern Africa's Stargazers – CNN's Inside Africa explores the history and bright future of astronomy in Southern Africa.

SCIENCE|BUSINESS

SKA: Major science project across three continents keeps running during the pandemic – While the COVID-19 pandemic is causing some delays, much science continues as normal.

TELESCOPE MAGAZINE

Expert Interview: Dr Robert Braun – The Japanese technology magazine talks in-depth with the SKA's science director about all aspects of the project (in Japanese).

SPIE

Drowning in Data – An in-depth look at how the SKA will handle the "data tsunami" it will generate.

COMING UP...

EUROPEAN ASTRONOMICAL SOCIETY ANNUAL MEETING (FORMERLY EWASS) – VIRTUAL MEETING
https://eas.unige.ch/EAS2020
29 June – 3 July 2020

30TH ANNUAL INCOSE INTERNATIONAL SYMPOSIUM – VIRTUAL EVENT
https://www.incose.org/symp2020/home
20 July – 22 July 2020

EUROSCIENCE OPEN FORUM (ESOF) – POSTPONED FROM JULY, NEW DATES IN SEPTEMBER 2020
https://www.esof.eu/en/
2 September – 6 September 2020
| Trieste, Italy

AUTUMN ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF JAPAN
http://www.asj.or.jp/nenkai/index-en.html
8 September – 10 September 2020
| Aomori, Japan

SPARCS X 2020 "CAPTURING SCIENCE FROM THE PATHFINDER SURVEY DATA"
https://www.idia.ac.za/SPARCS2020/
8 September – 11 September 2020
| Cape Town, South Africa

INTERNATIONAL CONFERENCE ON RESEARCH INFRASTRUCTURES (ICRI)
http://icri2020.ca/
30 September – 2 October 2020
| Ottawa, Canada

SPIE ASTRONOMICAL TELESCOPES AND INSTRUMENTATION – POSTPONED FROM JUNE 2020 TO DECEMBER 2020; MOVED FROM JAPAN TO USA
Conference Link
13 December – 18 December 2020
| San Diego, USA

SKA JOBS

CONTROL SYSTEM ARCHITECT
Deadline: 14/06/2020
Apply here

NETWORK ARCHITECT
Deadline: 28/06/2020
Apply here

As we continue to grow, new roles will continue to be advertised. To set up alerts and receive notifications when jobs are advertised, register on SKAO's recruitment website and follow us on LinkedIn.

PARTNER INSTITUTE JOBS

INSTITUTE OF ASTROPHYSICS OF ANDALUCIA (IAA)

Software Engineer Position at IAA-CSIC for SKA Regional Centre Activities
Deadline: Announced Soon
Apply here

Project Scientist position for the coordination of the Spanish participation in the SKA
Deadline: Announced Soon
Apply here

PARTNER PUBLICATIONS

READ THE LATEST SKA-RELATED NEWS FROM SOME OF OUR INTERNATIONAL PARTNERS

CSIRO MRO NEWS – APRIL 2020
ICRAR NEWS – JUNE 2020

SKA-FRANCE BULLETIN

MEDIA INAF LATEST SKA NEWS

ASTRON NEWS – JUNE 2020

RADIONET
RADIONET NEWSLETTER – MAY 2020

Contact – The SKA magazine

Published by the SKAO Communications team.

Editor: William Garnier
W.Garnier@skatelescope.org
Editorial team: Mathieu Isidro, Cassandra Cavallaro
skao-outreach@skatelescope.org
Design: Joe Diamond

Based on an original design from Carbon Creative.

We welcome your contributions to *Contact*!
Find out how to submit ideas here.

All images in *Contact* are courtesy of SKAO unless otherwise indicated.

About the SKA

The Square Kilometre Array (SKA) Organisation leads an international effort to build the world's largest radio telescope. The SKA will be constructed in Australia and South Africa with a later expansion in both countries and into other African countries. Its global headquarters is located at Jodrell Bank in the UK.

The SKA will conduct transformational science and help to address fundamental gaps in our understanding of the Universe including the formation and evolution of galaxies, fundamental physics in extreme environments and the origins of life in the Universe.

Front cover: The SKA-MPG prototype dish in the Karoo, South Africa. Credit: Enrico Sacchetti. All rights reserved.

For printed versions

Hyperlinks: *Contact* is produced primarily as a digital magazine. If you are reading a print copy, use the QR code to read this and other issues of *Contact* online and access the hyperlinks.