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The SKAO's Magazine

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Dear friends and colleagues,

As one sees the news from across the world, it seems to be an uncertain and challenging global environment at the moment and I hope therefore that reading our 14th edition of Contact will allow you, the reader, to focus your mind on something different and positive, even if only for a short time.

This edition carries a wide variety of stories: you'll be able to read about the construction highlights for both SKA-Mid and SKA-Low, these will be regular features in future editions of Contact. There are several stories relating to local stakeholder engagement in both of our telescope host countries, from supercomputing in Australia, through astro-tourism, to my favourite, students from Carnarvon High School in the Karoo, South Africa attending the World Robot Olympiad in Denmark, supported by our colleagues at SARAO.

We report on two milestones. The first is five years of ground-breaking science from MeerKAT. We have all seen the superb images and scientific results emerging from the science teams, making MeerKAT, I believe, the premier science instrument on Earth in its frequency range. In February 2024, our South African colleagues are organising a meeting to celebrate the achievements to date. A second milestone is that MWA, the Murchison Widefield Array, has marked a decade of operations and similarly spectacular science. It is undergoing an upgrade as it enters its final phase.

As we did last October in South Africa, just a few weeks ago we hosted the SKAO Council at the SKA-Low site in Western Australia. These visits are essential for Council to physically experience the scale and progress of the construction projects. It is one thing to receive updates in the Council Chamber at HQ, but quite another to walk the ground and gain an understanding of the challenges associated with building not one, but the two largest radio telescopes on Earth.

Finally, it is a pleasure to see, on the last page, a list of recent awards and honours to several members of the SKA community. I congratulate them all.

PROF. PHILIP DIAMOND,
SKAO DIRECTOR-GENERAL

ABOVE: *Prof. Phil Diamond and SKAO Council Chair Dr Catherine Cesarsky contribute to a collaborative artwork piece between SKAO Council members and Wajarri woman Susan Merry.*

School robotics teams fly the flag for South Africa internationally

BY SARAO

Two teams of students from Carnarvon High School, located close to the SKA-Mid site in South Africa, took part in the World Robot Olympiad Friendship Invitational Tournament, held in Odense, Denmark in September.

The Carnarvon teams – the Galaxy Guardians and City Mechanics – joined participants from 41 countries at the event. South Africa was one of four African countries represented at the competition alongside Egypt, Ghana and Kenya.

The students are part of the Robotics Schools Programme, which SARAO has been operating in the Karoo since 2016. Its aim is to develop and inspire interest in science, technology, engineering and maths (STEM) at schools near the site of the MeerKAT radio telescope, where SKA-Mid is now being built.

Participating in the Olympiad offered a myriad of benefits for the learners and their coaches, and proved to be a transformational experience. It introduced them to a global platform to showcase their STEM skills, fostered international collaboration, and exposed them to diverse perspectives in robotics. Additionally, it promoted critical thinking, creativity, and problem-solving abilities, which are vital for their future careers and personal development. As part of the experience, they had the opportunity to visit the renowned LEGO House in Billund.

"Competing again on a global stage allowed learners from Carnarvon High to challenge themselves and push their limits. The level of competition was extremely high, and motivated their best performance," said Odwa Magabuko, SARAO's Robotics Schools Programme Coordinator.

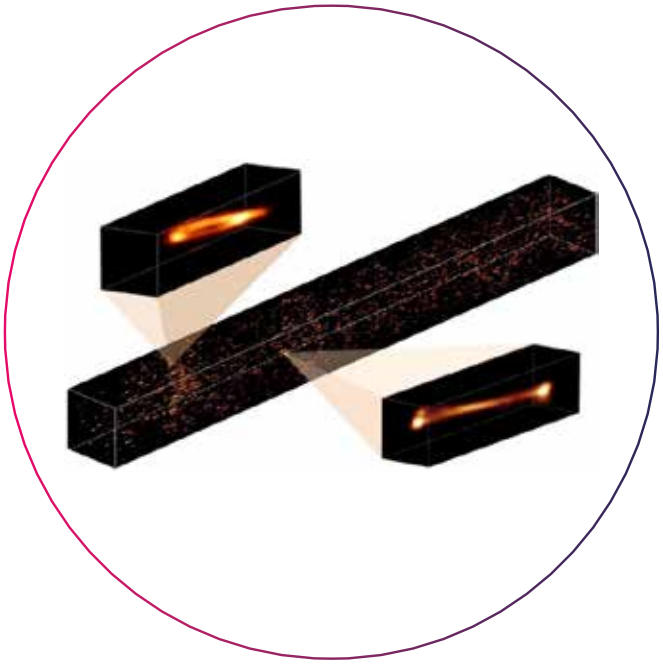
"Interacting with participants from different countries and cultures was truly enriching for the teams. They got the chance to learn from their perspectives, build friendships, and create lasting connections. Overall, the international competition provided a unique and fulfilling experience they will always cherish. This also acknowledges the dedication of the coaches who work with the learners."

ABOVE (left): *School teams (L-R): South Africa, Kenya and Egypt attending the robotics competition in Denmark. Credit: SARAO*
ABOVE (right): *The students joined 218 teams from 41 countries at the competition in Denmark. Credit: SARAO*

Science Data Challenge paper shares insights (and code)

BY CASSANDRA CAVALLARO (SKAO)

The SKAO's Science Data Challenge series is yielding valuable results for the science community in how to tackle the volume and complexity of future SKA data.



ABOVE: *The 3D data cube analysed in the challenge contained 2,683 sources. The challenge's 3D data cube is a series of stacked radio images, each reflecting a different frequency. It shows galaxies across a distance of 4 billion light years. Credit: SKAO*

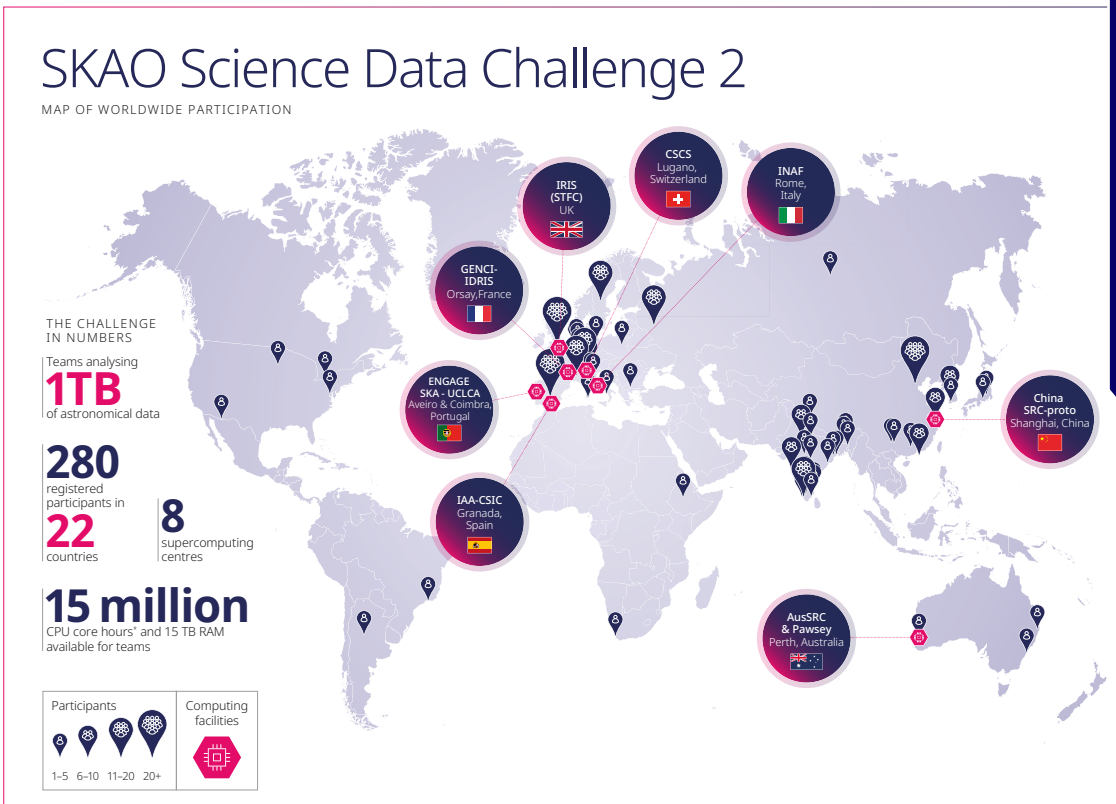
A recent paper, led by the SKAO Science team and published in the Monthly Notices of the Royal Astronomical Society, details the full results and lessons learned from the second Science Data Challenge, which ran in 2021. It asked teams to find and measure the neutral hydrogen content of galaxies in simulated SKA-Mid telescope data. The challenge received generous support from eight international supercomputing facilities, which provided dedicated resources for teams.

The paper features contributions from more than 100 participants, representing over 40 institutions in 18 countries. Along with details of how the SKAO's Science team simulated SKA-Mid's view of the neutral hydrogen sky, there are descriptions of the techniques – both new and established – that teams used to tackle the challenge. It also includes links to the source code for the simulations and some of the teams' methods.

The authors note that a combination of methods, and a collaborative, multidisciplinary approach, will be key to exploiting huge astronomical data sets like those the SKAO will create. The winning strategy combined predictions from two independent machine learning techniques to yield a 20% improvement in overall performance.

"By sharing the findings we're aiming to grow our collective knowledge and hopefully inform those beyond our immediate community, in a way that could feed other innovations," said SKAO Scientist Dr Philippa Hartley, who co-led the challenge. "That's why it was really important for us to publish the source code as well, as part of our goal to make science more open and more accessible."

Meanwhile the latest challenge – number three in the series – has now concluded. It tasked participants with the recovery of the most distant neutral hydrogen signatures from a simulation of the SKA-Low view of Cosmic Dawn. Watch out for the results in the next issue of Contact!



Work begins on supercomputing collaboration in Australia

BY JUAN CARLOS GUZMAN, SKA-LOW HEAD OF COMPUTING AND SOFTWARE

In early August, SKAO staff joined representatives from the Pawsey Supercomputing Research Centre in a workshop to begin negotiations on a collaboration agreement between the two organisations.

Pawsey will host the data centre for the SKA-Low telescope at its site in Perth, Western Australia – next door to the SKAO Science Operations Centre. The organisations have adopted the Vested® relational contracting methodology to develop this agreement, the same method used in the SKAO software contracts.

The main outcome of this workshop was the co-creation of a statement of intent, which includes a shared vision, guiding principles and intended behaviours for the collaboration agreement.

The SKAO-Pawsey team worked well together, bringing positive attitudes and energy to the workshop that is well aligned with SKAO values. It was an example of true collaboration between the two institutions. The aim of the team is to have the agreement ready for signature by the end of 2023.

The SKAO and Pawsey are similarly aligned in their commitment to sustainability in their design and operations, and excellence in their goals and achievements. Pawsey's newest supercomputer Setonix was named the most powerful public research supercomputer in the southern hemisphere and fourth greenest supercomputer in the world in November 2022.

Pawsey's Setonix currently processes data for SKA precursors in Australia, ASKAP and MWA, and the SKA-Low prototype instrument AAVS2. Data from the recently constructed final prototype AAVS3 will also soon be stored at Pawsey.

ABOVE: *The team working on the foundations of the SKAO-Pawsey collaboration agreement. Credit: SKAO*

Astro-tourism: bridging the cosmos and communities

The dark night sky of the Karoo is a natural resource that can help to create employment opportunities particularly for youth in the area. Credit: SKAO/SARAO

BY ALMA VIVIERS (SKAO)

Dark and quiet skies as a natural resource are vital for astronomical observation, and research can generate income for communities living in often remote locations.

Sadly, statistics abound about the steadily diminishing percentage of the global population who can still see the Milky Way with the naked eye. Urbanisation and the associated human activities mean more and more light is drowning out the night sky.

It is well understood that to conduct ground-breaking research in astronomy, astronomers require dark and radio-quiet skies – locations free from light pollution and the interference of radio frequency signals. Consequently, observatory sites are often situated in rural areas with low industrialisation and population, far removed from urban centres and the economic opportunities they hold.

The symbiotic relationship between astronomy and rural communities is where astro-tourism enters the stage. It offers a unique opportunity for these communities to harness dark and quiet skies as a natural resource to generate income. The South African National Astro-Tourism Strategy recognises this opportunity and seeks to leverage the presence of the MeerKAT and SKA-Mid telescopes to drive socio-economic growth in the surrounding Northern Cape region, which experiences high levels of unemployment and poverty.

One inspiring example of the initiative in action is the Carnarvon Astro-Guides. Amy-Lee Visagie, Brandon Booysen, Chrislin de Koker, Gillian Kammies, Kaylene Malgas and Nicole Vermeulen are the first cohort of the National Research Foundation-SARAO Astro-Tourism Training Programme, presented in collaboration with the South African Department of Economic Development and Tourism.

The six budding guides, recruited in March 2023 from the towns surrounding the SKA-Mid site, received training in astronomy, gaining insights into celestial phenomena, historical discoveries, and the underlying principles governing the Universe. This knowledge foundation equips them to communicate complex concepts to audiences effectively. They also received hands-on training to operate advanced telescopes, navigate the night sky, identify celestial objects, and conduct immersive guided dark sky tours. The programme also sought to foster their entrepreneurship, equipping them with skills and knowledge to operate their own astro-tourism enterprises.

What sets the Carnarvon Astro-Guides' approach to sky tours apart is their incorporation of local lore and stories about the heavens passed down for generations as part of the stargazing experience.

Celebrating local knowledge systems and heritage will be continued in the future Carnarvon Science Exploratorium, a project conceived by SARAO. Within the framework of the Astro-Tourism Strategy, the vision for the Exploratorium is to create an immersive astronomy experience as part of a bigger astro-tourism route. The preliminary design concept for the experiential centre was approved in September 2023 and detailed design development is underway. Once completed, the centre will play an important part in science engagement and educational support activities in the broader region. The interweaving of science and culture underscores the vital role of astro-tourism in revitalising not just the economy but also the cultural heritage of these communities.

Astro-tourism in South Africa has the potential to be more than just stargazing; it can be a powerful vehicle for socio-economic growth, cultural preservation, and scientific education.

To learn more about their work or to book a sky viewing, follow the Carnarvon Astro Guides on Facebook.

Sunrise over the fly camp. Credit: Ventia

SKA-Low construction highlights

BY ANT SCHINCKEL, SKA-LOW SITE CONSTRUCTION DIRECTOR

From groundworks and preparation for the first antenna installations, to establishing a paramedic service for on-site staff, it's all go at the SKA-Low site.

First infrastructure works begin

September saw the first SKA-Low telescope-related infrastructure take place at Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory. This included the first earthworks for the antenna arrays that comprise AA0.5 – the first six stations of the telescope, on the southern spiral arm.

The first clearing works were performed by Wajarri Holdings, a Wajarri-owned and operated business subcontracted by Ventia, which marked the occasion with a celebratory on-site event supported by the SKAO. Guests included representatives from the SKAO, Ventia, CSIRO, Wajarri Holdings, Wajarri Yamaji Aboriginal Corporation (WYAC), Wajarri Enterprises Limited, Aurecon and on-site subcontractors.

Four Wajarri companies have now been subcontracted for on-site infrastructure work for the project. More than 30 Wajarri people have been employed on the project on site, including infrastructure and civil works, camp village and transport, with additional Wajarri people employed through WYAC and CSIRO as heritage monitors.

A 103-bed temporary "fly camp" was also opened, providing accommodation for staff, contractors and visitors while construction of the permanent 200-bed construction camp progresses.

There has been a lot of progress on site since the celebration. Significant clearing, trenching and backfilling work has been done at the AA0.5 telescope stations, and power and fibre optic cables have begun to be laid. The pouring of the foundations for the remote processing facilities for AA0.5 has commenced. The on-site connections to existing fibre optic cables that link to supercomputers located more than 600 km away at the Pawsey Supercomputing Research Centre in Perth will be installed in the coming months. As of early November, around 80% of the core area has been cleared in preparation for infrastructure works.

AAVS3 commissioning underway

The team completed installation of Aperture Array Verification System 3 (AAVS3), the final SKA-Low technology demonstrator on site. AAVS3 is the first instrument owned, operated and maintained by SKAO staff in Australia. Representing a single complete SKA-Low station, AAVS3 is being used to trial an alternative layout, with a goal of confirming the layout with the least possible electrical interference between antennas. It is also an opportunity to test the building processes of the first SKA-Low stations, as well as the first building blocks for the verification of the telescope. With power and fibre cables connected, testing and commissioning has been taking place in collaboration with partners at Curtin University.

The SKAO team in Australia recently captured the "first light" from AAVS3, meaning the first image of the sky taken by a telescope after construction. The scientists produced

the first "fringes" which measure the interference patterns produced by pairs of antennas, effectively confirming that the telescope is working correctly. The fringes were then processed after calibration to generate an image of the full sky above the station, showing the radio trace of our galaxy, as well as the Sun and the Centaurus A galaxy.

Site safety

With staff and contractor safety the highest priority during construction and beyond, the SKAO has awarded a contract to St John Ambulance WA to provide paramedic support on the SKA-Low site. A paramedic will be based on site to provide medical assessment, treatment and clinical care during the day, as well as be on-call for after-hours support.

Care for the environment

As construction progresses, the SKAO's ecological and environmental commitments are paramount, and are already being put into action. The region which is becoming home to SKA-Low is also home to a vulnerable species of lizard: the western spiny-tailed skink. To ensure construction operations don't impact this native creature, the first western spiny-tailed skink survey programme took place in September, with SKA-Low staff accompanying a fauna specialist as they searched for evidence of the lizards' presence. No evidence was found, and the first clearing permit was issued for clearing work associated with AA0.5. That is not the end of the checks though, and a small number of SKA-Low staff in Australia have since been approved as fauna specialists to lead future surveys.

Watch: A new technology demonstrator for SKA-Low

SKAO and CSIRO staff at the infrastructure milestone event. Credit: Ventia

SKA-Low Telescope Director Dr Sarah Pearce at the fly camp. Credit: Ventia

Wajarri woman Gail Simpson speaking at the infrastructure milestone event. Credit: Ventia

SKA-Mid interim Engineering Operations Centre (iEOC), Klerefontein. Credit: SKAO

SKA-Mid construction highlights

BY TRACY CHEETHAM, SKA-MID SITE CONSTRUCTION DIRECTOR

The SKA-Mid team has been working non-stop on infrastructure development, environmental assessments, and making a difference in the local labour market.

Getting ready for the construction crew

Set up has begun on the SKA-Mid contractor camp, just 15 km from the telescope core, which will house up to 275 people. Facilities company CSG will manage the camp, and it has begun hiring local residents from the established labour database for essential services such as housekeeping, catering, and security. The interim Engineering Operations Centre at Klerefontein is expanding as well, with extra space and service connections to accommodate the growing team.

Infrastructure rollout

The essential infrastructure for SKA-Mid is rapidly being developed, with the initiation of road construction, electrical and fibre systems, antenna foundations, and monitoring equipment, essential for the contractor camp and telescope assembly.

Geotechnical investigations have been completed in accessible areas, and environmental surveys will soon follow, spanning approximately 52 km of overhead infrastructure on National Research Foundation (NRF)-owned land and the telescope's three spiral arms.

Safety remains our top priority, and the SKA-Mid Health, Safety and Environmental team are carrying out twice-weekly safety inspections alongside monthly audits. Part of operating safely in such a remote environment is ensuring people can communicate across the site, so EMCOM Communications is helping to establish a low-frequency communication network. This will provide connectivity across the SKA-Mid core and spiral arms, but within stringent frequency parameters to ensure that the MeerKAT radio telescope's sensitive observations are not disturbed.

Water conservation

These infrastructure developments go hand–in–hand with implementing environmental plans and procedures, part of the Observatory-wide commitment to sustainability. That includes the start of environmental training for SKA-Mid construction teams, conducted by infrastructure contractors Power Adenco, focusing on protected plants and species of conservation concern found at the telescope site.

Water conservation is crucial in the Northern Cape, and water extraction from on-site boreholes is being closely monitored. "Greywater" from the construction camp is being repurposed for dust suppression during construction.

Making strides on local participation

One way the SKAO seeks to create a broader impact is through a commitment to local participation in the construction phase, to enhance local economic and human capital development.

Infrastructure contractor Power Adenco is making significant strides in this area, following extensive consultations with local communities and the establishment of an independent database of available skills and local business enterprises.

Thirty-eight local individuals have already found work on the contract, both with Power Adenco and CSG, the camp manager contractor.

To address the challenges local unemployed individuals face in accessing training, Power Adenco is funding 10 local people to complete a National Certificate in Construction Supervision over the next 12 months. They will then serve as on-site construction supervisors, and be equipped to find further employment in the construction sector in the future.

Progress on access and construction licences

A plethora of licences and agreements necessary for SKA-Mid construction have been secured in collaboration with our partners:

- 72 of the 74 servitudes, which grant the right to run infrastructure on farmers' land in the spiral arms, have been secured, with ongoing negotiations to finalise the remaining ones. The land acquisition programme for SKA-Mid is at an impressive 97% completion.
- All the necessary construction licences for NRF-owned land are in place, ensuring a smooth start to construction.
- SARAO received a flora permit from the Northern Cape Department of Nature Conservation in July, which will allow the SKAO to relocate protected plant species when infrastructure rerouting is not feasible. Protected species will be relocated into other areas in the Meerkat National Park under the supervision of South African National Parks, or to the Karoo Botanical Garden.

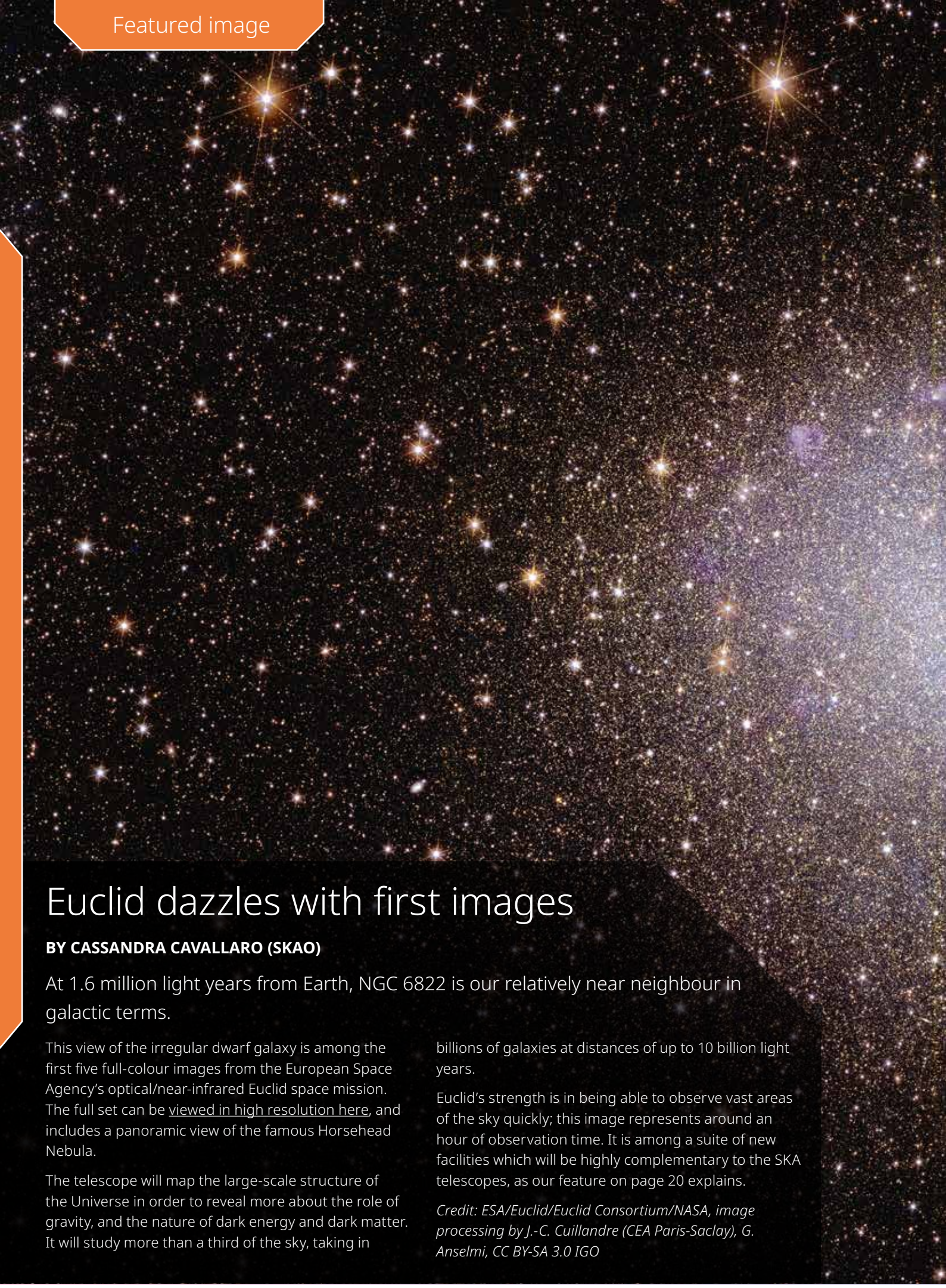
Geotechnical drilling in the SKA-Mid Core. Credit: SKAO

Establishment of Portacabins and bulk service connections at the SKA Mid Contractor Camp Credit: SKAO

BEYOND THE SITE

- **September saw a major milestone achieved in China, where the 54th Research Institute of China Electronics Technology Group Corp (CETC54) completed the first SKA-Mid production dish.** The "big lift" of the main reflector onto its pedestal took place at a test site in Shijiazhuang. This completed dish structure is undergoing further in-situ testing, while a second dish is approaching completion and will become the first of the four-dish array (known as AA0.5) to be shipped to South Africa.
- **The initial components of the AA0.5 dishes have started to arrive in Cape Town. These components include a tilt sensor from Jewell Instruments in the United States.** Extreme temperatures and wind mean the metal dish moves, expands and contracts causing minute inaccuracies in the precision of pointing the dish for observations. While some of this deformation can be modelled and compensated for, the tilt sensor functions as a type of "auto-correct" in real time. Instead of placing the sensor at the central axis of the dish, where it is subject to distortion from the dish rotating, the team have opted for an off-axis placement to ensure more accuracy.
- **The SKA-Mid Assembly, Integration and Verification (AIV) and Integrated Testing Facility team has successfully completed a readiness review that demonstrates the testing environment – set up to test the signal chain – is ready for action.** The test environment includes a sky simulator, designed and assembled by the AIV team at the interim Science Operations Centre, which mimics radio signals received by the dishes during observation.
- **The roll out of SKA-Low telescope SMART boxes, which will provide electrical power to the antennas and collect signals received from the sky to go off-site for processing, has begun in Australia.** Perth-based company AVI is contracted to build up to 12,000 of the boxes for the entire fit-out of SKA-Low. Teams from the International Centre for Radio Astronomy Research's Curtin University node designed and built the first set of 24 SMART boxes, which were 10 years in the making.
- **Work is underway to manufacture a reverberation chamber for SKA-Low activities in Australia, which will be used to undertake the emissions compliance testing of SKA-Low telescope systems and associated hardware**. The €1m contract will be fulfilled by Spanish company EMITE OTA test systems, together with Australian partner company Maser.

Featured image



Euclid dazzles with first images

BY CASSANDRA CAVALLARO (SKAO)

At 1.6 million light years from Earth, NGC 6822 is our relatively near neighbour in galactic terms.

This view of the irregular dwarf galaxy is among the first five full-colour images from the European Space Agency's optical/near-infrared Euclid space mission. The full set can be viewed in high resolution here, and includes a panoramic view of the famous Horsehead Nebula.

The telescope will map the large-scale structure of the Universe in order to reveal more about the role of gravity, and the nature of dark energy and dark matter. It will study more than a third of the sky, taking in billions of galaxies at distances of up to 10 billion light years.

Euclid's strength is in being able to observe vast areas of the sky quickly; this image represents around an hour of observation time. It is among a suite of new facilities which will be highly complementary to the SKA telescopes, as our feature on page 20 explains.

Credit: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi, CC BY-SA 3.0 IGO

The software developers catching gravitational waves

BY SEBASTIAN NEUWEILER (SKAO)

As several SKA pathfinder telescopes detected the strongest evidence yet for low-frequency gravitational waves (see page 24), in the inner east of Melbourne, Australia, a software company also had reason to celebrate.

ABOVE: *Fourier Space co-founders Andrew Jameson and Willem van Straten.*

Fourier Space company is behind pulsar timing array software and instrumentation used by radio astronomy observatories globally, including Parkes' multibeam pulsar signal processor and MeerKAT's pulsar timing processor.

Born from a desire to enable astronomy and space entities to solve their signal acquisition and processing challenges rapidly and effectively, Fourier Space CEO and co-founder Andrew Jameson said the skills and software libraries of the team had been honed over decades of instrumentation development for radio astronomy.

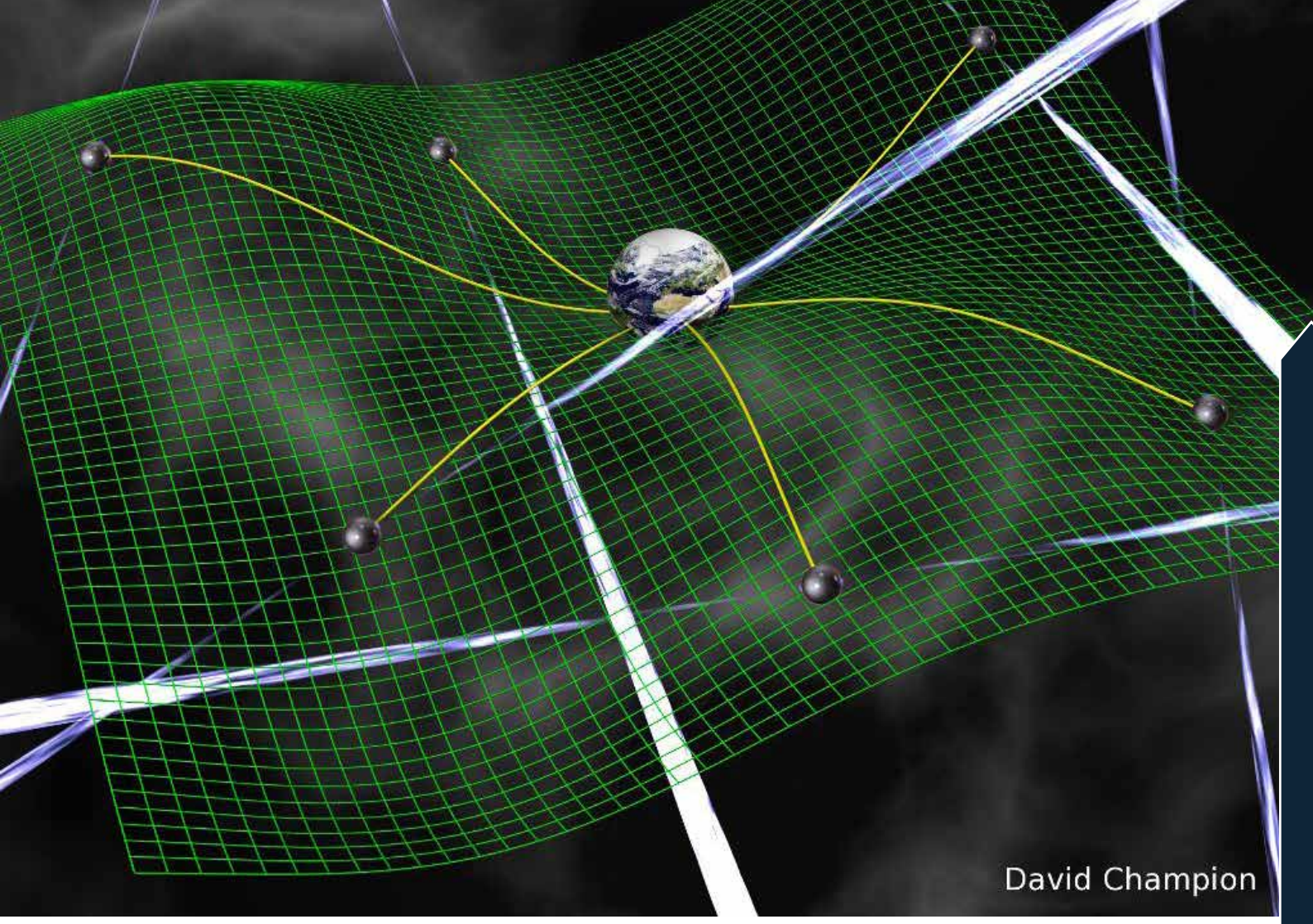
"Not only do we want to work on the technical aspect, but we also care deeply on the scientific outcome, with everyone in the company having a very strong background in pulsar astronomy," he said.

"A lot of the data that was recorded and collected as evidence of low-frequency gravitational waves was done with software our team had designed and contributed to. There's a great sense of collective accomplishment, that you're part of the engineering right up to discovery in science.

"That's exactly what we want to do in our involvement in the SKA endeavour: be able to build over the next several years the instrumentation that will lead to the next generation of breakthroughs and cutting-edge science."

The team has also designed the SKAO's pulsar timing processor, which will be deployed at the Australian and South African sites to observe multiple pulsars in parallel. This will be accomplished by processing multiple phased-array beams, each pointing to a different spot on the sky, from the correlator beamformer of the central signal processor.

ABOVE: *Both the MeerKAT telescope (left) and CSIRO's Parkes radio telescope, Murriyang (right) have made use of the pulsar timing software and instrumentation. Credit: SARAO & CSIRO*



ABOVE: *Pulsar timing arrays are searching for low-frequency gravitational waves by regularly observing many millisecond pulsars and analysing the arrival times of their radio pulses. Credit: David Champion/Max Planck Institute for Radio Astronomy*

Fourier Space co-founder Willem van Straten, who led the pulsar timing pre-construction team for the SKA telescopes, said the team's approach utilised "coherent de-dispersion" to completely correct the dispersive effects of the interstellar medium.

"The usual way we think of dispersion is through a rainbow, different wavelengths travelling at different speeds when they're not travelling through a vacuum," he said. "It's what causes red and purple to refract at different angles when they go through glass and radio waves to travel at different speeds through the interstellar medium. De-dispersion allows you to fully correct that in a way that other techniques can't, as it reveals the high time resolution in the pulsar signal. It's that high time resolution structure that allows you to achieve the highest timing precision."

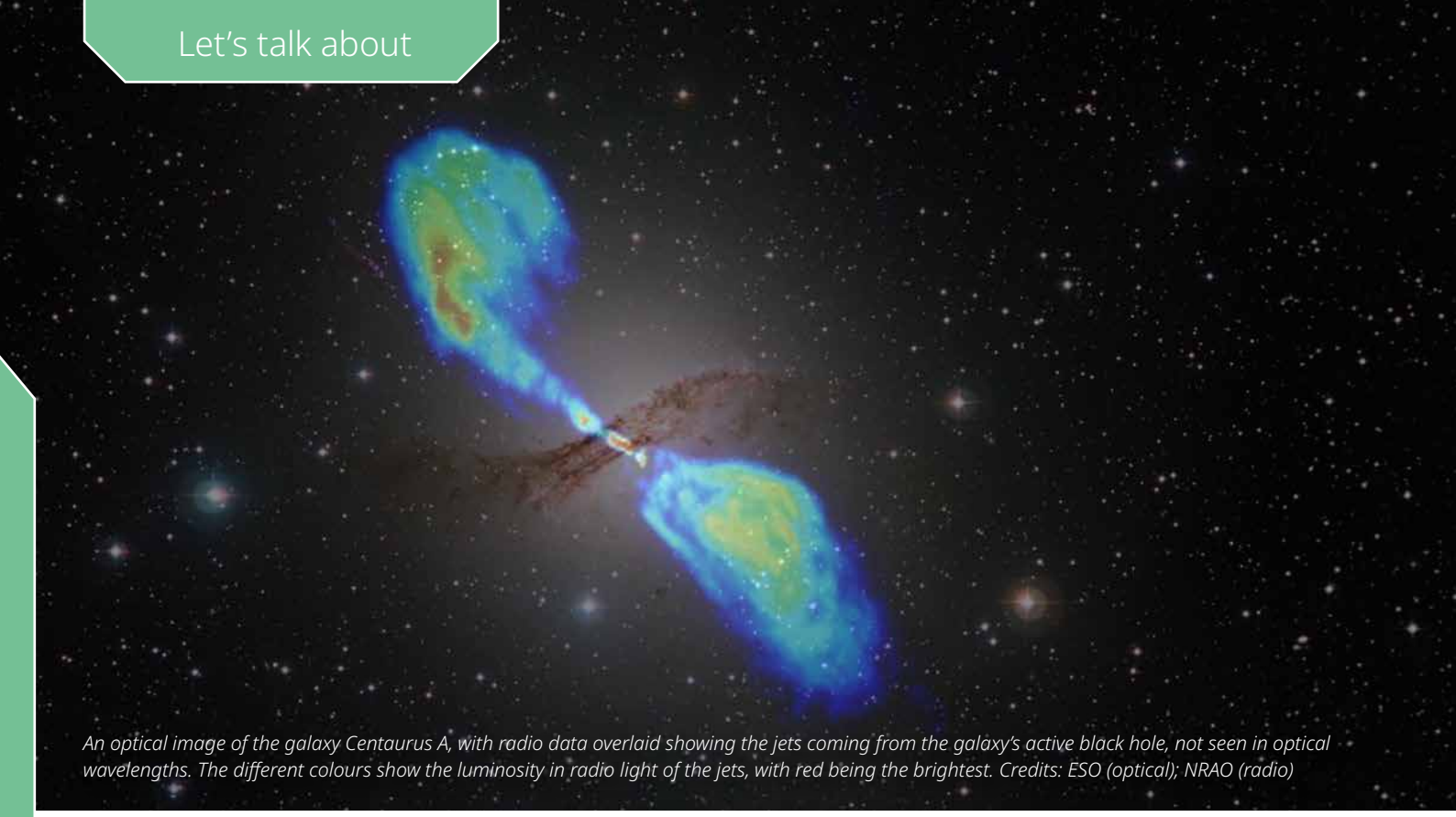
The pulsar processors designed by Fourier Space will be capable of coherently de-dispersing over 1 GHz of bandwidth in real time for timing and searching applications. Jameson said this would allow the SKA telescopes to have significantly more instantaneous bandwidth and observational power than other instruments.

"The software scales on that computing power, but there's a lot of things that enable that right through the whole design of the telescopes," he said.

"From the receivers, which sample a large bandwidth, to the stages of signal processing that occur which accommodate those large bandwidths, to then forming multiple beams and looking at different pulsars simultaneously to increase your efficiency.

"The SKA telescopes are really going to represent a big step forward in gravitational wave astronomy, particularly with the number of pulsars that they will observe."

> *"There's a great sense of collective accomplishment, that you're part of the engineering right up to discovery in science."*
>
> **ANDREW JAMESON, FOURIER SPACE CEO AND CO-FOUNDER**



An optical image of the galaxy Centaurus A, with radio data overlaid showing the jets coming from the galaxy's active black hole, not seen in optical wavelengths. The different colours show the luminosity in radio light of the jets, with red being the brightest. Credits: ESO (optical); NRAO (radio)

Let's talk about... multi-wavelength astronomy

BY MICHELLE WHEELER AND CASSANDRA CAVALLARO (SKAO)

In November, ESA's optical/near-infrared Euclid telescope released its first full-colour images of the cosmos. Launched in July 2023, it's part of a new generation of telescopes which will be highly complementary, enabling astronomers to observe the same regions, objects and phenomena in great detail at different wavelengths, to create the most complete picture ever of our Universe.

At the heart of the most turbulent galaxies in the Universe lies a supermassive black hole that's actively swallowing up anything that gets a bit too close to its extreme gravitational pull. Some of the material, though, is saved from the brink, instead being ejected in powerful jets that can travel millions of miles an hour, close to the speed of light.

"This is a violent process," says SKAO Senior Scientist Dr Anna Bonaldi. "It releases a lot of energy and this leads to jets of emission that can be, in some cases, much bigger and much more luminous than the galaxy itself."

HOW MASSIVE IS SUPERMASSIVE?

Supermassive black holes are a million to over a billion times as massive as our Sun.

Radio telescopes can observe these jets in detail. But look with an optical telescope – one that observes the light that can be seen with the human eye – and the galaxy might just look like a very bright star.

This is just one example of "multi-wavelength astronomy" – using telescopes that observe at different wavelengths to look at the same object in space to create a more complete picture of the processes at work.

"All the objects in the sky – the stars, the galaxies, everything – they emit light on a broad spectrum of wavelengths," she says. "If you look at something in just one wavelength, you might see that there is an object there. But you might not be able to really identify what it is, where it is, what kind of physical and chemical processes are taking place, or how the object is interacting with its surroundings."

The wavelength emitted depends on the process behind what astronomers are seeing. Here's an example: earlier this year, one of the most violent explosions in the Universe, a gamma-ray burst, was detected. Gamma rays and X-rays – their spectrum neighbours – are thought to be emitted when massive stars explode and collapse into black holes, spewing out material in the process. On this occasion, the event was also detected by the Australian SKA Pathfinder Telescope (ASKAP) radio telescope, but what it saw were radio waves produced when the ejected material collided with the surrounding matter, creating shockwaves.

Let's take a closer look at a couple of the SKA's science goals which lend themselves to multiwavelength studies, with the help of some more experts.

Transient events

Oxford University Head of Astrophysics Prof. Rob Fender is a member and former co-chair of the SKAO's Transients Science Working Group, studying some of the most extreme phenomena in our Universe, including supernovae, merging neutron stars, and ultra-relativistic jets coming from black holes.

For him, multi-wavelength astronomy has been crucial to unearth the connection between the material being accreted and jets being emitted around black holes, a process that also occurs with some neutron stars. Both objects are created when massive stars die; the most massive form black holes, while the less massive become neutron stars.

"The inner accretion flow – hot matter spiralling down into the gravitational potential, releasing energy as it does so, 'powering' the black hole – emits in the X-ray band, whereas the relativistic jet – which carries away some mass and a lot of energy from the accretion flow – is most prominent in the radio band," he says.

"Only by making extensive simultaneous observations of these kinds of objects with orbiting X-ray observatories and ground-based radio arrays were we able to discover clear patterns which, it turns out, seem to hold for all black holes on all mass scales across the Universe."

Time for a short digression to explore another "multi" tool that astronomers can now call upon to get a better look at the Universe: multi-messenger astronomy

The different wavelengths of the electromagnetic spectrum are a product of one type of messenger: radiation, or light. But there are others, too: neutrinos, cosmic rays, and gravitational waves, often poetically described as ripples in space-time.

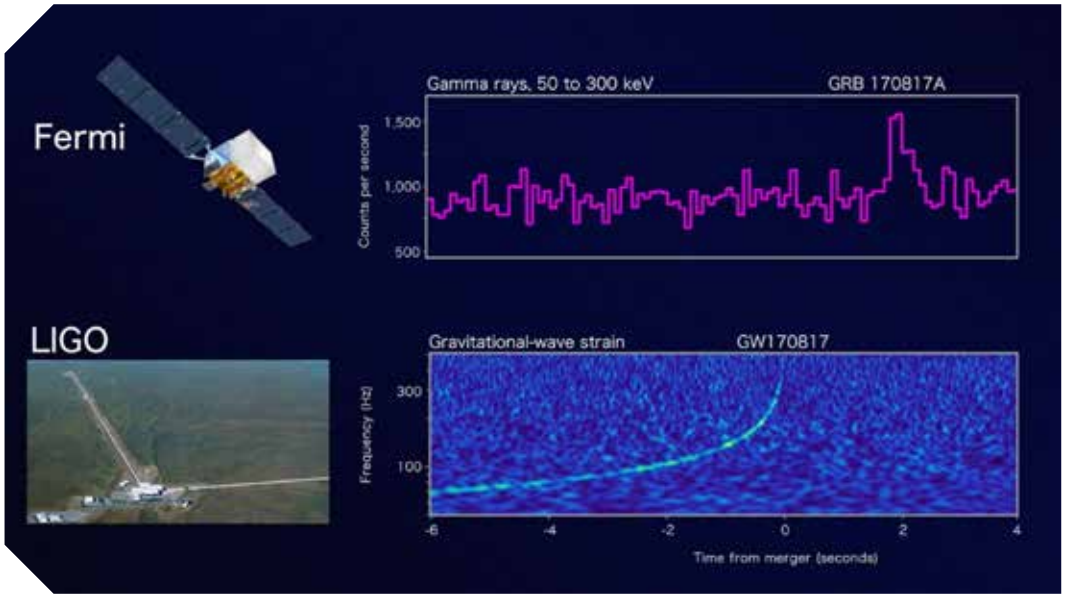
The first direct detection of gravitational waves – resulting from the merger of two stellar-mass black holes – was made in 2015 by the Laser Interferometer Gravitational-wave Observatory (LIGO). Since then, gravitational wave science has given us a host of "firsts".

In August 2017, came the first cosmic event in history to be observed in both gravitational waves and light. The event, known as GW170817 (named for the date it was detected), was caused by the spectacular collision of two neutron stars. About two seconds after the gravitational waves were detected, light associated with the same event was detected at different wavelengths.

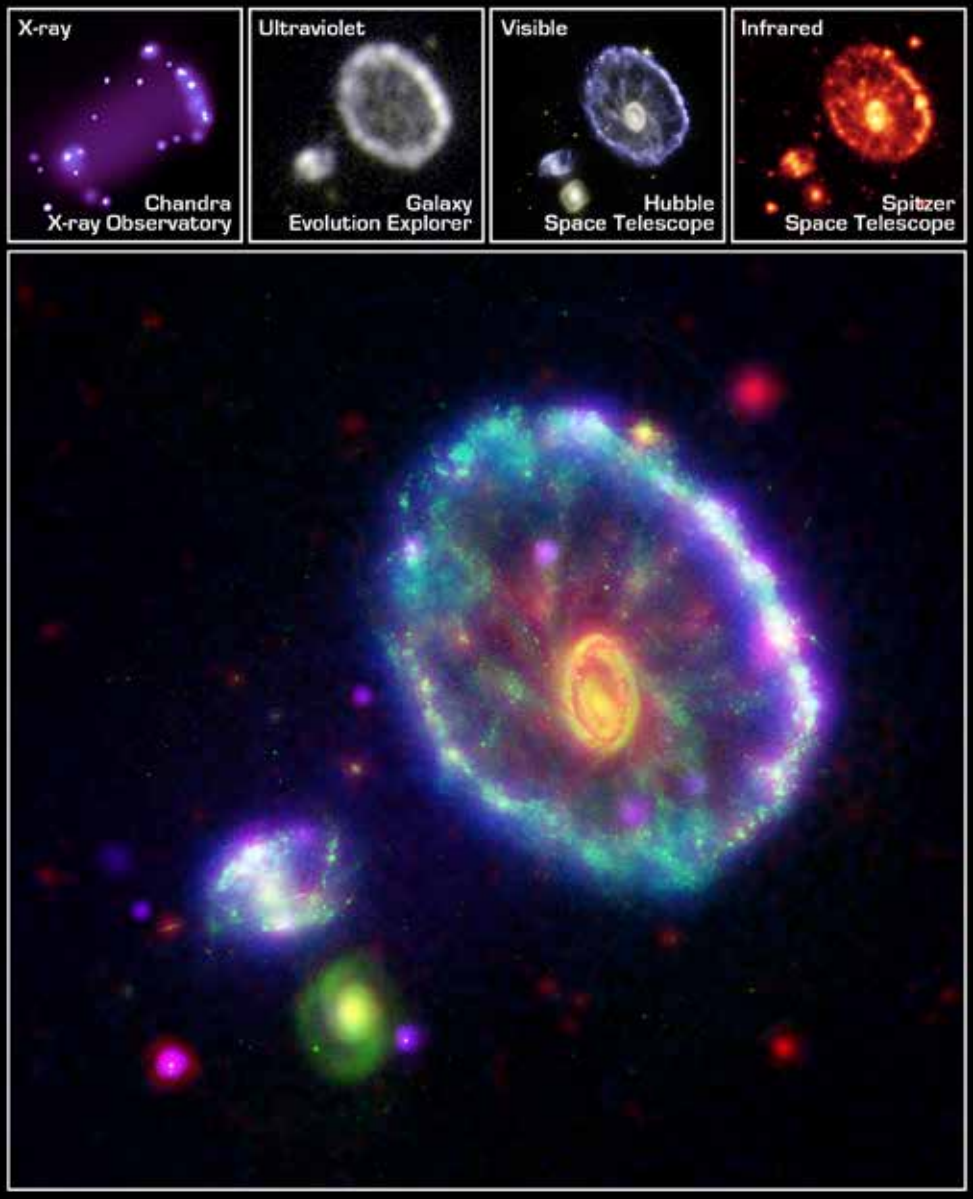
"First gamma-ray and then optical emission was detected. The optical emission appears to originate in a 'kilonova' associated with a large mildly relativistic mass ejection accompanied by radioactive decay," Rob explains. "Later on, an X-ray and radio counterpart was discovered arising from a completely different phenomenon – once more a relativistic jet.

"Three completely different energy release channels – gravitational wave burst, kilonova and relativistic jet – required observations at different wavelengths and cadences to fully understand. Without this breadth of view, we have a very restricted understanding of these events, which could easily lead to incomplete or even incorrect models."

The SKAO will also be a multi-messenger facility, capable of detecting gravitational waves by observing their ripple effect on nearby pulsars, and studying the composition of cosmic rays interacting in Earth's atmosphere with unprecedented precision.



ABOVE: *GW170817 marked the first time a cosmic event – in this case the merger of two neutron stars – had been seen in both gravitational waves and light. The gravitational wave was detected by LIGO (bottom) and its counterpart gamma ray burst, which occurred less than two seconds later, by the FERMI gamma ray observatory in space. Credit: NASA GSFC and Caltech/MIT/LIGO Lab*



This multi-wavelength view of the Cartwheel galaxy shows how different wavelengths provide different insights. In the main image, Chandra X-ray Observatory's data is shown in purple; Galaxy Evolution Explorer's far ultraviolet data is in blue; the Hubble Space Telescope's visible light data is green; the Spitzer Space Telescope's infrared observations are shown as red. Credit: NASA/JPL-Caltech/P. N. Appleton (SSC-Caltech)

Galaxy evolution

Back on the electromagnetic spectrum, the study of galaxies can also be greatly enhanced through a multi-wavelength approach. Dr Isabella Prandoni, based at the Italian National Institute for Astrophysics (INAF), is an expert on galaxy formation and evolution, and a member and former chair of the SKAO's Extragalactic Continuum Science Working Group.

"Only through observations along the entire range of the electromagnetic spectrum is it possible to get a full census of the physical processes that take place in galaxies and black holes over cosmic time, probe the various galaxy components (stars, gas, dust, relativistic plasma), and link them to the evolutionary properties of galaxies as a whole," she says.

One key way of exploring galaxy evolution is through studying how and when stars have formed in galaxies, known as the star formation history of the Universe, Isabella explains. This requires estimating star formation rates, and a reliable estimate can't be achieved without using different wavelengths.

"Ultraviolet/optical star formation rate indicators based on stellar emission from young, hot stars are widely used, but are typically affected by dust attenuation, as dust preferentially absorbs the emission at short wavelengths, where young stars dominate," she says. "Alternatively, one can rely on observations in the mid/far infrared bands, which are sensitive to the stellar light reprocessed by the dust [the dust absorbs the light and re-radiates it at longer wavelengths] providing complementary information, particularly for dusty galaxy populations."

Of course, radio astronomy enthusiasts know that radio waves are immune to dust, although observing them can be difficult.

"The radio band offers a uniquely valuable tool thanks to its lack of sensitivity to dust. This however requires very deep observations [observing for a long time], because we're looking for something called synchrotron radiation. It's emitted in the radio band by cosmic rays which have been accelerated in supernovae remnants – these remnants are tracers of recent star formation, but their radio emission is very weak.

"A common approach is then to combine investigations based on these different indicators to obtain the most complete census of star formation in galaxies."

Collaborating across the spectrum

Telescopes around the world already work together within an alert system to observe unusual or transient objects that appear in the sky, and the SKA telescopes will join that effort. But the SKAO is also planning different kinds of collaborations.

Anna and her colleagues are already laying the groundwork for the SKAO to work with other major space and ground-based observatories including the James Webb Space Telescope (JWST), the European Space Agency's Euclid mission, and the Cherenkov Telescope Array Observatory (CTAO).

"There is a fleet of new instruments in operation or soon to be coming online, and we are already working through the potential synergies between the science cases," she says.

Earlier this year, the SKAO and European Southern Observatory (ESO) put that into action, with a conference on how to maximise the science impact of their telescopes through joint surveys of the southern sky.

"If two instruments observing at different wavelengths want to do a survey of the sky, why not choose the same region at the same time?" Anna says. "The results can still be used for the observatories' respective science goals, but can also become part of revealing something even bigger by being used in combination with each other."

For Isabella, all major new-generation facilities are set to play an important role in her research into galaxy evolution.

"Indeed, most of the deep radio surveys I'm involved in with SKA precursor telescopes make extensive use of multi-band optical or infrared ancillary datasets," she says.

"The ALMA telescope in Chile is playing a transformational role in our understanding of the cold gas content of galaxies across cosmic time. JWST will transform our understanding of galaxy formation and evolution, thanks to its sharp view of the high-redshift Universe."

In the future, Isabella is very excited about the possibility of combining SKA data with Euclid surveys, and potentially those of the planned Next-Generation Very Large Array (ngVLA).

"The Euclid and SKA HI [neutral hydrogen] surveys combined will provide an unprecedented picture of the large-scale structure, well beyond the local Universe," she says. "And the SKA and the ngVLA combined will revolutionise our understanding of the role of jet-induced active galactic nuclei feedback in galaxy evolution."

Meanwhile Rob's transient studies with the SKA telescopes will be complemented by gamma-ray and X-ray telescopes in space.

"If you look at something in just one wavelength, you might see that there is an object there. But you might not be able to really identify what it is."

DR ANNA BONALDI, SKAO SENIOR SCIENTIST

"The SKA telescopes will transform observations of transient jets across a huge range of angular scales, and will be greatly enhanced by working with other facilities. From the ground, ALMA is very exciting to study the early-time evolution of jets," he says. "CTA will also be very exciting to see if our relativistic jet sources are also producing very high energy gamma-rays, which many models predict they should."

Seeing beyond light

The advent of multi-messenger astronomy also adds the potential for synergies with other science facilities.

"These new additions – neutrinos, gravitational waves, cosmic rays – are a bit of a revolution because after centuries of just having the light, it's very exciting to be looking at different signals entirely," Anna says.

"Whenever you add a measurement that you were not able to do before, or a big improvement in a measurement that you could do before, there are always surprises, we find things we didn't know existed.

"That's very likely with the SKA telescopes and with the other new instruments, and by combining their capabilities. I think there's going to be something unexpected."

EXPLORING THE UNIVERSE WITH SUPERHUMAN VISION

Most of the light – or radiation – in the Universe is invisible to human eyes. But astronomers have access to the whole range, known as the electromagnetic spectrum, thanks to telescopes specifically designed to detect other types of light beyond optical wavelengths.

Look at a rainbow in the sky and you'll see red, orange, yellow, green, blue and violet light. If your eyes could see past red on the rainbow, you'd be able to see infrared light. That's what some snakes and bats can see. Unfortunately it's also how bloodsuckers like mosquitos and bed bugs find their way to us. We can join the infrared party, but only by donning night vision goggles.

If you could see past violet, you would see ultraviolet – or UV – light, painfully familiar to those of us who have stayed in the sun too long. Birds and bees can see this. On the next page we look at several planned telescopes and the light they will be able to see.

Telescopes to watch

The SKA telescopes will complement a host of groundbreaking telescopes in other wavelengths. Here's a taste of the telescopes coming online now or in the near future.

Atacama Large Millimeter/ submillimeter Array (ALMA) – Atacama Desert, northern Chile

Wavelength: Radio

Led by: European Southern Observatory / US National Radio Astronomy Observatory / National Astronomical Observatory of Japan

Positioned in one of the highest and driest places on Earth, ALMA Observatory consists of 66 high-precision antennas and can produce images clearer than the Hubble Space Telescope.

Next Generation Very Large Array (ngVLA) – New Mexico, United States

Wavelength: Radio

Led by: US National Radio Astronomy Observatory

Currently in the early stages of development, the ngVLA will be the largest telescope array in North America when completed. It has been designed to observe at wavelengths complementary to the SKA telescopes.

James Webb Space Telescope – In orbit

Wavelength: Infrared (and some optical)

Led by: NASA / European Space Agency / Canadian Space Agency

Launched on 25 December 2021, the James Webb Space Telescope is the largest, most powerful and most complex telescope ever launched into space. It orbits the Sun, 1.5 million kilometres away from the Earth

Extremely Large Telescope (ELT) – Atacama Desert, northern Chile

Wavelength: Optical and infrared

Led by: European Southern Observatory

With a mirror 39m in diameter, the ELT will gather 100 million times more light than the human eye. The telescope is currently under construction, and will be the largest visible and infrared light telescope in the world

Euclid – In orbit

Wavelength: Optical and infrared

Led by: European Space Agency / the Euclid consortium / NASA

Launched in July 2023, the Euclid space telescope is designed to understand the nature of dark matter and dark energy. The image quality will be at least four times sharper than that achieved by telescopes on Earth.

Cherenkov Telescope Array Observatory (CTAO) – Canary Islands / Atacama Desert, northern Chile

Wavelength: Gamma ray

Led by: A consortium involving more than 150 institutes in 25 countries

The world's first open ground-based gamma-ray observatory, the CTAO will have sites in both the northern and southern hemispheres. It is expected to survey the sky hundreds of times faster than existing gamma-ray telescopes.

Images credit (right): www.chromoscope.net

Radio

Neutral hydrogen

Microwave

Far infrared

Near infrared

Hydrogen α

Visible

X-ray

Gamma ray

More MeerKAT: Celebrating five years of operations, citizen science, and future horizons

BY ALMA VIVIERS (SKAO)

In July 2023 the MeerKAT radio telescope celebrated five years of operations. This article reflects on its stellar achievements, how it engages citizen scientists, and the MeerKAT+ extension project.

Five years of MeerKAT observations

From giant radio galaxies to hydroxyl megamasers, MeerKAT has been delivering groundbreaking scientific observations since its inauguration in July 2018. In these five short years, unplanned discoveries are already emerging from the unprecedented amounts of data the telescope has collected.

In July 2023, the South African Radio Astronomy Observatory (SARAO) celebrated this milestone.

"MeerKAT has not only transformed our understanding of celestial phenomena but is also become a testament to the collaborative spirit and creativity driving African innovation in radio astronomy," said Pontsho Maruping, Managing Director of SARAO, expressing thanks to government and industry partners, academics, and of course the SARAO team.

To honour the release of its inaugural research paper, the MeerKAT@5 conference will be hosted by SARAO and the Department of Science and Innovation in February 2024, and promises to reflect on the telescope's accomplishments not only in science but also engineering innovation and human capacity development.

Bursts from Space project

This anniversary also marks the start of a new era for the world-class facility, which will make some of the collected data accessible to the general public. Employing Zooniverse, the world's largest people-powered research platform, a research team from the University of Oxford aims to harness the collective effort of volunteers worldwide to make discoveries and contribute valuable datasets to the research community. The "Bursts from Space" citizen science project, powered by MeerKAT's ThunderKAT survey, invites members of the public to scrutinise radio sources for potential transients and variables.

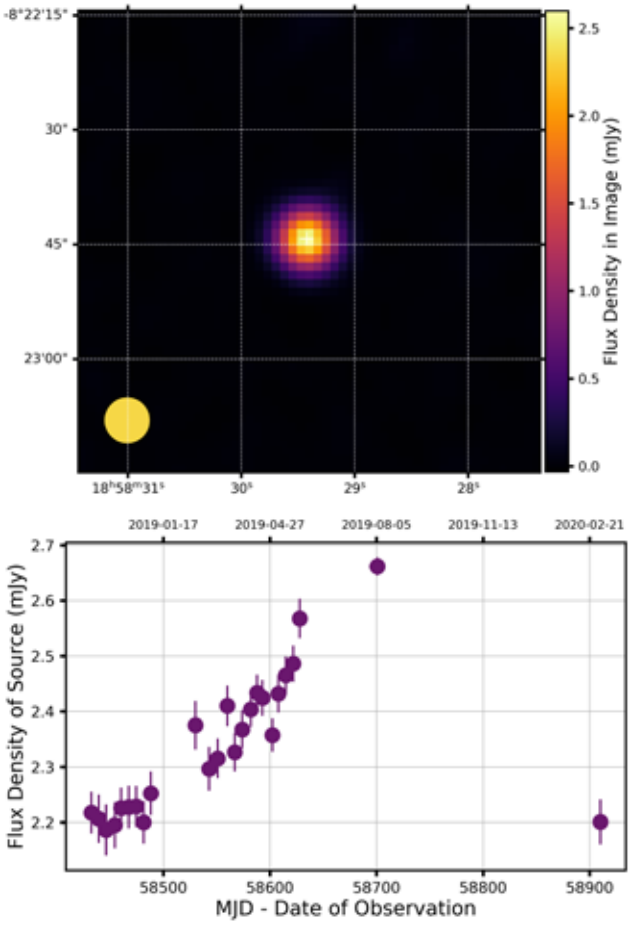
While machines assist in this endeavour, human eyes have proven invaluable. By presenting both images and light curves, volunteers recognise subtle patterns and contribute nuanced understanding, to distinguish between genuine astrophysical phenomena and artifacts or anomalies introduced during the data processing pipeline. Currently there are 1,082 volunteers and more than 200,000 classifications have been done.

MeerKAT+ and its progress

The MeerKAT extension project, or MeerKAT+, spearheaded by SARAO in partnership with the Germany's Max Planck Society and Italy's National Institute for Astrophysics, is poised to elevate the telescope's scientific capabilities. This extension involves the addition of up to 20 new dishes. Notably, the increased distance between dishes, from 8 km to 17 km, promises heightened observation sensitivity and sharper radio images.

The MeerKAT+ project, initiated in 2019, is currently under construction on-site in the Karoo, with integration and science commissioning slated for early 2025. Ultimately, the extension will be integrated into SKA-Mid, making up part of the 197-dish array.

BELOW: *In the Bursts from Space citizen science project, participants are shown images of radio sources and light curves to determine if a source is radio-variable or transient. Credit: Bursts from Space: MeerKAT*



Murchison Widefield Array reaches historic milestone

BY ICRAR/CURTIN UNIVERSITY

The Murchison Widefield Array (MWA), the longest-running SKA precursor instrument, has marked a historic decade of operations ahead of its crucial final phase.

To mark the occasion, members of the global astronomy community gathered in Perth to hear about the latest in MWA science.

MWA Director Prof. Steven Tingay said it was a significant milestone for the project – a powerful telescope made up of 8,192 antennas spread across more than 30 km^2 on Wajarri Yamaji land in Western Australia.

"It's a point in time to look back and reflect on the origin of the project and all the trials and tribulations we went through to design and build and then start operating the telescope," he said.

"It's also a chance to look back on all the amazing science we've done over that time.

"In the next 12 months, a major upgrade to the MWA's facilities in Western Australia will enable it to generate four times more data than it ever has, while doubling its sensitivity to probe even deeper into the secrets of our Universe."

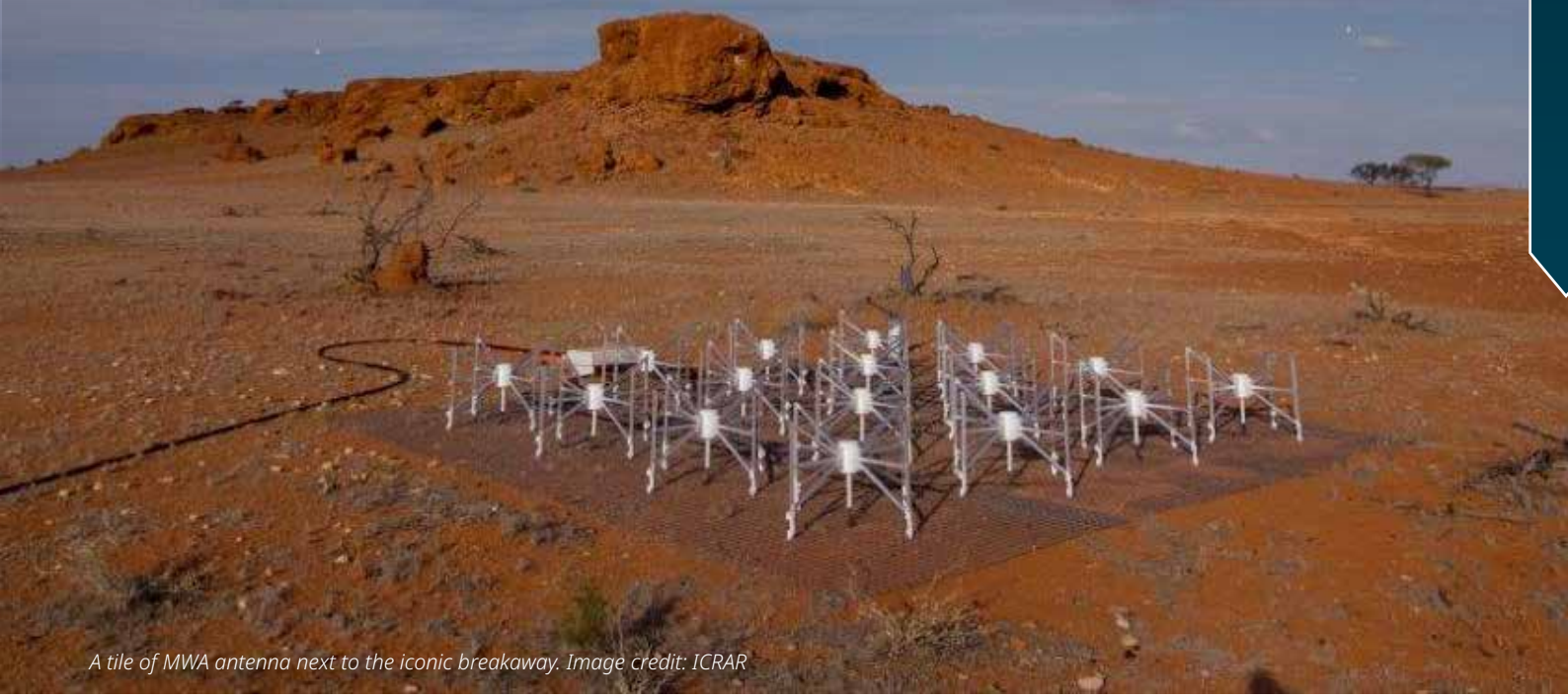
Led by Curtin University, with more than 20 research partners in six countries, the MWA is one of the fundamental stepping stones to the SKA telescopes and has been at the forefront of international astronomy since it started operations in 2013.

Over the past decade, the MWA has catalogued and surveyed hundreds of thousands of galaxies, with more than 47 PB of data collected and stored in the Pawsey Supercomputing Research Centre in Perth.

It detected the **largest-known eruption in the Universe** since the Big Bang, discovered **new types of exotic celestial objects** that generate periodic bursts of radio waves, and even revealed previously unknown structures in the Earth's uppermost atmosphere.

It was used to discover a mysterious object in our galaxy – possibly a dead star with an intense magnetic field that produces powerful bursts of radio waves every 22 minutes (see page 25). The MWA has also determined new limits on the Epoch of Reionisation, the period when the first stars and galaxies formed, and has produced an all-sky survey that resulted in **the first radio-colour panorama of the galaxy.**

Switzerland has recently joined the international MWA Consortium, bringing a group of Swiss universities into the project's family. As MWA's sixth participating country, Switzerland joins Australia, Canada, China, Japan, and the USA, and brings exciting scientific and technical capabilities to the MWA team, in addition to its involvement in the SKAO.



A tile of MWA antenna next to the iconic breakaway. Image credit: ICRAR

ABOVE: *An artist's impression showing supermassive binary black holes generating gravitational waves which ripple across the Universe, passing several pulsars on their way to Earth. Credit: Danielle Futselaar / MPIfR*

SKA pathfinders provide strongest evidence yet for low-frequency gravitational waves

BY ANIM VAN WYK (SKAO)

In multiple scientific articles published in June, astronomers detailed the results of decades of observations to spot ripples in spacetime by focusing on extinguished stars called pulsars.

Among the facilities involved were several SKA pathfinders – designated telescopes or systems undertaking SKA-related technology, science, or operations activities:

- China's Five-hundred-meter Aperture Spherical Telescope (FAST)
- Radio Telescope Effelsberg in Germany
- India's Giant Metrewave Radio Telescope (GMRT)
- CSIRO's Parkes radio telescope, Murriyang, in Australia
- Arecibo Telescope in Puerto Rico, which held SKA pathfinder status until its 2020 collapse.
- Westerbork Synthesis Radio Telescope/APERTIF in the Netherlands
- Lovell Telescope in the UK, part of the SKA pathfinder eMERLIN

Though scientists using the Laser Interferometer Gravitational-Wave Observatory (LIGO) achieved the first direct observation of gravitational waves in 2015 – about a hundred years after they were first theorised by Albert Einstein – it involved measuring interference in laser beams, not radio waves emanating from pulsars. These waves were then traced to the collision of two stellar-mass black holes 1.3 billion light-years ago.

The most likely origin of low-frequency gravitational waves is the cosmic distribution of binary black-hole systems weighing millions to billions of solar masses, formed when galaxies frequently collided and merged in the early Universe. These lower frequencies cannot be measured by detectors on Earth. The long distance between Earth and pulsars, which lie beyond our Solar System, enables lower frequency waves to be detected.

Senior scientist at the Max Planck Institute for Radio Astronomy and core member of the SKA Pulsars Science Working Group, Dr David Champion, explained: "Pulsars are excellent natural clocks. We use the incredible regularity of their signals to search for tiny changes in their ticking to detect the subtle stretching and squeezing of spacetime by gravitational waves originating from the distant Universe."

The results are now being pooled through the International Pulsar Timing Array consortium to confirm what would be the first detection of gravitational waves using pulsars. These efforts will expand this emerging area of science, which forms a key SKA science goal.

"The latest findings mark the culmination of decades of effort in precision pulsar timing," said the SKAO's Science Director, Dr Robert Braun. "They are a major step towards opening this exciting new window into gravitational wave physics. The SKA telescopes' contribution to precision pulsar timing will undoubtedly provide new insights, in addition to also allowing individual merger events and late stage in-spirals to be witnessed."

Astronomers find new type of stellar object hiding in plain sight

BY ICRAR

An international team of astronomers has discovered a new type of stellar object that challenges our understanding of the physics of neutron stars.

Until recently all known magnetars, a rare type of star with extremely strong magnetic fields that can produce powerful bursts of energy, were thought to release energy at intervals ranging from a few seconds to a few minutes.

The newly discovered object emits radio waves every 22 minutes. Lead author Dr Natasha Hurley-Walker said it was the longest period magnetar ever detected, and was likely a rare type of star with extremely strong magnetic fields that can produce powerful bursts of energy.

"This remarkable object challenges our understanding of neutron stars and magnetars, which are some of the most exotic and extreme objects in the Universe," she said.

"The discovery not only has important implications for our understanding of the physics of neutron stars, but the behaviour of magnetic fields in extreme environments. It also raises new questions about the formation and evolution of magnetars and could shed light on the origin of mysterious phenomena such as fast radio bursts."

Led by astronomers from the Curtin University node of the International Centre for Radio Astronomy Research (ICRAR), the discovery of the magnetar, named GPM J1839-10, was made using the Murchison Widefield Array, a radio telescope on Wajarri Yamaji Country in outback Western Australia.

The stellar object is only the second of its kind ever detected.

Other telescopes, including three CSIRO radio telescopes in Australia, the MeerKAT radio telescope in South Africa, and the XMM-Newton space telescope followed up to confirm the discovery as well as learn more about the object's unique characteristics.

Not all magnetars produce radio waves, with some existing below the "death line", a critical threshold where a star's magnetic field becomes too weak to generate high-energy emissions. Dr Hurley-Walker said the object they had discovered was below this death line, as it was spinning too slowly to produce radio waves.

"Assuming it is a magnetar, it shouldn't be possible for this object to produce radio waves – but we're seeing them," she said.

"Every 22 minutes, it emits a five-minute pulse of radio wavelength energy, and it's been doing that for at least 33 years."

The research team plans to conduct further observations of the magnetar to learn more about its properties and behaviour.

BELOW: *An artist's impression of the Murchison Widefield Array radio telescope observing the ultra-long period magnetar. Credit: ICRAR*

Astronomers discover galaxy wrapped in a ribbon

BY JAMES CHESTERS (CSIRO)

A study by an international team of astronomers using CSIRO's ASKAP radio telescope suggests that unusual polar ring galaxies may be more common than we think.

The small spiral galaxy NGC 4632 lies surrounded by a ring of cool hydrogen gas, stretching like a delicate ribbon made of cosmic dust, gas and stars at right angles to its spiral disk. It can only be detected by highly sensitive radio telescopes like ASKAP, which is located on Wajarri Country in Western Australia.

It's one of two potential polar ring galaxies described in a new paper in the Monthly Notices of the Royal Astronomical Society.

Prof. Kristine Spekkens, SKA Canadian Science Director, led the research with Dr Nathan Deg for Queen's University in Canada, as part of ASKAP's WALLABY survey.

"These results are a really nice illustration of the tremendous value of mapping the sky more deeply and more widely than has ever been done before," Prof. Spekkens said. "This is serendipity at its best: we found things we certainly didn't expect to find."

Assuming that NGC 4632 and the more distant galaxy NGC 6156 are polar ring galaxies, researchers calculated the proportion that can be detected in the WALLABY survey. Based on this calculation and the size distribution of the galaxies, the results suggest 1% to 3% of nearby galaxies might have polar rings. This is much higher than suggested by observations from optical telescopes.

Although not the first polar ring galaxies found, these would be the first observed using ASKAP.

CSIRO's Dr Bärbel Koribalski, co-author of the paper and one of the founders of WALLABY, said the survey will observe the whole southern sky to detect and visualise the gas distribution in hundreds of thousands of galaxies. So far it has mapped 600 galaxies in its pilot phase.

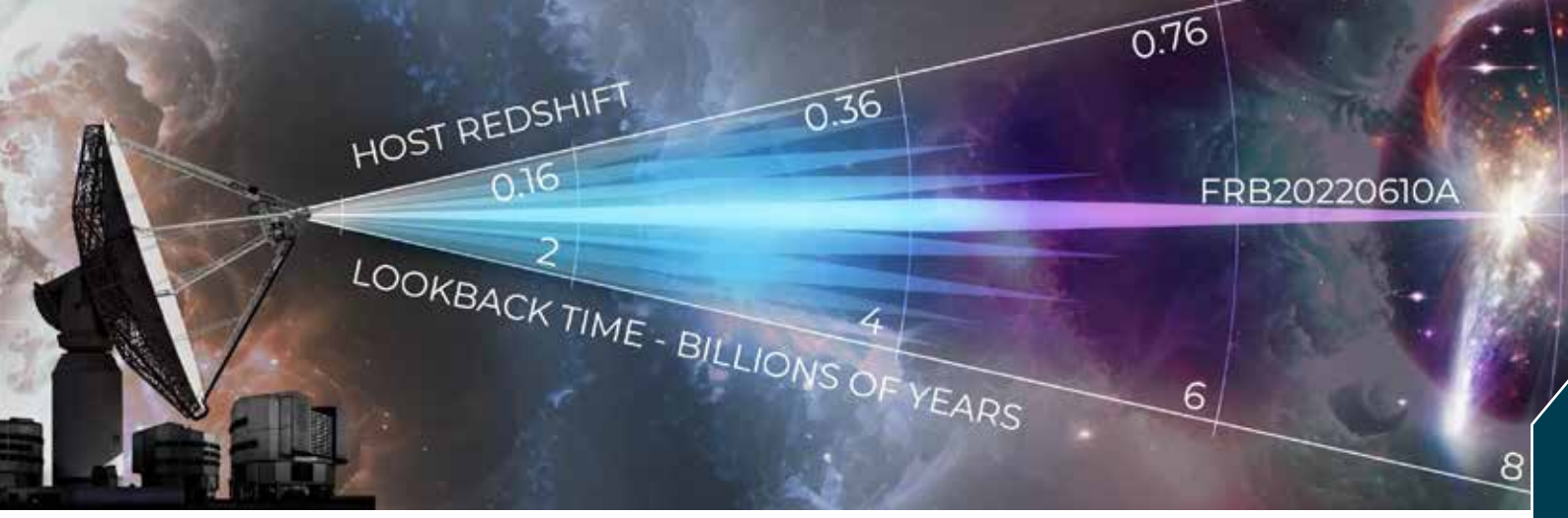
"Using ASKAP over the coming years, we expect to reveal more than 200,000 hydrogen-rich galaxies, among them many more unusual galaxies like these," Dr Koribalski said.

Why polar rings exist is still a puzzle. One explanation is that their stellar rings, which appear blended with gas clouds, may be shredded material cannibalised from a passing galaxy.

In the future, the enigmatic galaxies can be used to learn more about dark matter, using the polar rings to probe the shape of dark matter, which could give new clues about its mysterious properties.

BELOW: *Dr Jayanne English, an expert in astronomy image-making at the University of Manitoba, combined data obtained from ASKAP with optical and infrared data from the Subaru telescope in Hawaii to make the dramatic composite image of NGC 4632. Credit: J. English (U.Manitoba), with support of T. Jarrett (UCT) and the WALLABY team: ATNF/ASKAP:Suburu/Hyper Suprime Camera*

ASKAP is part of CSIRO's Australia Telescope National Facility and is a precursor to the SKA telescopes currently being built in Australia and South Africa. CSIRO's ASKAP telescope is located at Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio Astronomy Observatory. We acknowledge the Wajarri Yamaji as the Traditional Owners and native title holders of the observatory site.



ABOVE: *Artist's impression of the fast radio burst and the instruments used to detect and locate it, CSIRO's ASKAP radio telescope and ESO's Very Large Telescope. Credit: Carl Knox (OzGrav/Swinburne University)*

Record-breaking fast radio burst is most distant ever detected

BY MACQUARIE UNIVERSITY AND THE SKAO

Scientists have discovered an eight-billion-year-old fast radio burst (FRB) – the most ancient and distant located to date.

In a paper published in *Science*, a global team led by Macquarie University's Dr Stuart Ryder and Swinburne University of Technology's A/Prof. Ryan Shannon, report on their discovery, which smashes the team's previous record by 50%.

FRBs are a key science interest for the SKA Observatory, and authors of the paper include SKAO Postdoctoral Fellow Dr Hao Qiu and several members of the SKAO's Science Working Groups.

The discovery was made using CSIRO's ASKAP radio telescope in Western Australia and ESO's optical Very Large Telescope (VLT) in Chile.

The source of the burst was shown to be a group of two or three galaxies that are merging, supporting current theories on the cause of fast radio bursts. The team also showed that eight billion years is about as far back as we can expect to see and pinpoint fast radio bursts with current telescopes.

ASKAP detected the burst, named FRB 20220610A, on 10 June 2022. It was created in a cosmic event that released, in milliseconds, the equivalent of our Sun's total emission over 30 years. ASKAP was used to determine precisely where the burst originated, and the VLT enabled the team to search for the host galaxy.

The study is a prime example of the new era of multi-wavelength astronomy, where facilities observing different types of light are used together to reveal more than they could do individually. (Read more on page 16)

"Radio observations give us key information that allows us to measure the turbulent magnetised interstellar and intergalactic medium between us and the host galaxy. Optical observations play a complementary role by enabling us to identify the distance of the host galaxy and learn more about the host and foreground environment along the line of sight," Dr Qiu said.

"Comparing the radio and optical data allows us to test cosmological models of the intergalactic medium and better understand what could create these bursts."

The paper confirms that FRBs are common events in the cosmos and can be used to measure the "missing" matter between galaxies, to better understand the structure of the Universe.

"If we count up the amount of normal matter in the Universe – the atoms that we are all made of – we find that more than half of what should be there today is missing. We think that the missing matter is hiding in the space between galaxies, but it may just be so hot and diffuse that it's impossible to see using normal techniques," Dr Shannon said.

"Fast radio bursts sense this ionised material. Even in space that is nearly perfectly empty they can 'see' all the electrons, and that allows us to measure how much stuff is between the galaxies."

ASKAP is currently the best radio telescope to detect and locate FRBs, until the SKA telescopes (currently under construction in Australia and South Africa) come online.

Discovery of a neutral hydrogen halo surrounding the Whale galaxy

BY A/PROF. JING WANG (PEKING UNIVERSITY) AND PROF. LISTER STAVELEY-SMITH (ICRAR)

Observations with China's Five-hundred-metre Aperture Spherical Telescope (FAST) have helped to shed new light on the process that forms galaxies from diffuse gas.

A team led by scientists at Peking University combined the FAST observations with data from the Westerbork Synthesis Radio Telescope (WSRT) in the Netherlands in the study. The results have been published in The Astrophysical Journal.

By combining the sensitivity of FAST with the resolution of the WSRT, they were able to image vast amounts of diffuse gas surrounding the galaxy group known as NGC 4631, and observe a previously unseen "halo" component that may have resulted from cooling of the ionised gas widely surrounding galaxies.

Galaxies like our Milky Way were not built in a day. Instead, they had been growing gradually by accreting surrounding hydrogen gas to form stars. Yet most of the hydrogen, as the basic chemical element, still floats in the vast Universe in the form of gas. A fundamental question in astronomy is why and how does this hydrogen gas accrete onto galaxies, and what are the obstacles limiting the rate of accretion?

To answer this question, the hydrogen gas needs to be traced on extremely large scales – the size of a dark matter halo that provides most of the gravity to form galaxies – to much smaller ones, comparable to a star-forming gaseous clump.

Neutral hydrogen (HI) can provide crucial clues on both scales. On the scale of dark matter halos, HI observations strongly constrain the temperature and pressure conditions of gas accretion, while on sub-galactic scales, the observations constrain the physical conditions within the galactic disks where stars are formed.

Traditional interferometric radio telescopes (which use multiple antennas acting as one telescope) have been very helpful in mapping the neutral hydrogen in nearby galaxies with a resolution sufficient to resolve star-forming clumps, but they struggle to simultaneously capture the more diffuse and extended neutral hydrogen. This is because interferometers have less sensitivity at large spatial scales, where the signals are confined to the very shortest baselines.

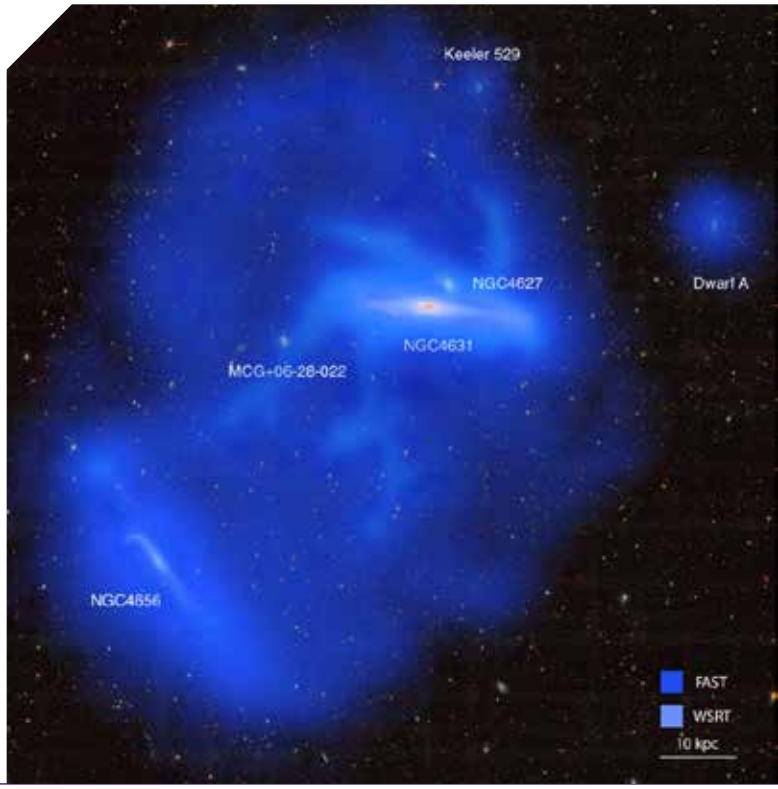
The SKA telescopes, with many antennas in the core and short baselines between them, will be able to simultaneously resolve structures of many sizes. In the meantime, the most promising way is using large single-dish radio telescopes, in conjunction with interferometers, to fill in the "gaps" and detect and resolve the large-scale missing hydrogen.

The image below highlights a successful effort in this direction, combining data from the currently largest single-dish telescope, FAST in China, with the deepest interferometric data so far from the HALOGAS survey taken by the WSRT.

The combined data reveals a newly detected neutral hydrogen halo in dark blue around the dense neutral hydrogen disk in light blue of the galaxy NGC 4631, also known as the Whale. The neutral gaseous halo, which previously has mostly been seen only in numerical simulations, marks a possible transitional stage between the hotter, ionised halo gas and the cool, neutral disk gas. This halo-like shape suggests that the hydrogen gas does not abruptly shift between the two phases, at least in this system, but first enters a "warm" state which has not been observed before.

This finding suggests a new world to be discovered in galactic neutral hydrogen science with the ongoing efforts of building new radio instruments, including the SKA telescopes.

BELOW: *A false colour image demonstrating the NGC 4631 group and its HI gas. On top of the optical image, the blue-coloured halo shows the diffuse gas imaged by FAST, while the light-blue finer structures are denser gas previously detected in the WSRT HALOGAS (Heald et al. 2011) observation. Credit: Jing Wang*



Robots help to maintain China's 'Sky Eye'

BY PROF. CAIHONG SUN (GUIZHOU RADIO ASTRONOMICAL OBSERVATORY)

China's FAST is the largest single-dish radio telescope in the world. Known as China's Sky Eye, safely maintaining its vast structure is a significant challenge – one that now has the help of a crew of… robots.

The FAST Operation and Maintenance Robot System was set up in December 2019 by the National Key Research and Development Programme of China, with the goal of enabling maintenance checks which are difficult – or sometimes impossible – to achieve manually. In July this year, the robots passed a performance evaluation.

One of them is designed to check the system of steel cables and pulleys that support FAST's feed cabin, which receives radio signals reflected off the collecting surface. The cables keep it suspended 140 m above the surface, so maintenance is crucial for the telescope's safe operation, but manual inspections are problematic for engineers, particularly the sections within 200 m of the feed cabin which are hardest to reach. The new feed support cable and pulley detection robot has a traction system which allows it to move along the cable, even at a steep angle, to check all the components, including clamps, pulleys, optical and electrical cables. It has robotic arms equipped with cameras to perform the inspections, and a magnetic sensor to detect internal defects in the cable.

Another robot is tasked with maintaining the telescope's laser targets, of which there are 2,225 distributed on FAST's reflector. They are the reference points for measuring the surface shape of the dish, which is composed of aluminium plates with a thickness of only about 1 mm. The surface cannot bear the full weight of a person, and until now the solution was to attach a large balloon to maintenance personnel to support their weight – a weather-dependent and inefficient approach. The new robot is lighter, more efficient, and can remove, clean and replace the targets by itself.

There are also robotic helpers to monitor radio interference, to disassemble and assemble the receivers, and to maintain the dish's more than 2,000 hydraulic actuators, responsible for manipulating the reflective surface to direct waves from different directions into the receiver.

The robots operate during regular maintenance periods, to avoid interfering with the telescope's astronomical observations.

This project was undertaken by the Guizhou Radio Astronomical Observatory with contributions from nine facilities including the National Astronomical Observatories of the Chinese Academy of Sciences and Harbin Institute of Technology.

ABOVE: *The reflector laser target maintenance robot. Credit: Guizhou Radio Astronomical Observatory*

ABOVE: *Prof. Philip Diamond, director-general of the SKAO, and his counterpart at the European Southern Observatory, Prof. Xavier Barcons, signed a cooperation agreement in July 2023. Credit: ESO*

SKAO signs collaboration agreement with ESO

BY ANIM VAN WYK (SKAO)

The only two intergovernmental organisations dedicated to ground-based astronomy have strengthened their ties with a collaboration agreement.

The SKAO's Director-General Prof. Philip Diamond and his European Southern Observatory (ESO) counterpart, Prof. Xavier Barcons, signed the agreement in July at the ESO Headquarters in Garching, Germany. ESO operates three observing sites in northern Chile on behalf of its 16 member states.

The agreement establishes a general framework for cooperation and information-sharing between the SKAO and ESO. It will promote strategic coordination of the organisations' long-term plans, allowing them to advance their aims in science together. Potential areas of coordination that have been identified include:

- strategic planning and governance
- international relations
- sustainability, diversity, equity, and inclusion
- communication, outreach, and publishing.

Examples of collaboration between the organisations since the SKAO's establishment in 2021 include advocating for the need to protect the dark and quiet skies and organising joint workshops, including one about surveying the southern skies.

"I am happy to formalise what has been a fruitful link since before we started setting up the SKAO," said Prof. Diamond. "As ESO's junior in the intergovernmental organisation world by nearly 60 years, the SKAO has had a great example to emulate and learn from. In turn, we have been able to set up an Observatory tailor-made for the 21st century and can share the experience we have gained."

SKAO Council makes first trip to Australia

BY LIZ WILLIAMS (SKAO)

In October, the SKAO Council was welcomed to Perth, Western Australia, for the first meeting in the host country since the SKA Observatory (SKAO) was established.

More than 50 delegates from SKAO member and partner countries, as well as SKAO senior leadership staff, attended the Council meeting, which included a visit to the SKA-Low telescope site.

Sharing Wajarri culture and heritage

The trip was an opportunity to highlight the importance of the partnership with the Wajarri Yamaji, Traditional Owners and native title holders of Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory, where SKA-Low is being built.

Wajarri Yamaji Aboriginal Corporation (WYAC) representatives Jennylyn Hamlett, Russell Simpson and Gailrose Simpson delivered a special presentation to the SKAO's top body about the perspective of the Wajarri Yamaji on the project.

Speaking to the Council, Jennylyn emphasised the importance of preserving Wajarri culture.

"We rely on our culture, it's a priority to our Wajarri people," she said.

"When we came to the conclusion that [the Wajarri] would be a partner and walk side by side with SKAO and CSIRO, it was for the betterment of our future generations – to empower our children."

She also spoke about the cultural heritage management plan that is in place to protect Wajarri heritage as part of the SKA-Low telescope construction and operations.

"It's our security blanket, it protects what we have out there, because without [our culture] we have nothing," Jennylyn said.

As part of the visit to site, delegates participated in artistic and language experiences, including a Welcome to Country in Wajarri language with Wendy Merry and English with Anthony Dann. Council also contributed to a collaborative artwork led by Susan Merry and participated in a language activity led by Leonie Boddington that had visitors learning their honorary Wajarri name for the day, such as marlu daanjamanmanha (kangaroo dancing) or gudurdu nyaan-nyaan (heart whispering).

Cultural awareness training

Many delegates also participated in full-day, Wajarri-led cultural awareness training sessions, which provided a thought-provoking and, at times, confronting insight into the experience of Aboriginal people in Australia, both historical and contemporary. The training also showcases the richness of Wajarri culture and heritage, which stretches back tens of thousands of years on the land, as well as language and Indigenous astronomy. The training is mandatory for all people who will visit the observatory for more than five days per year, but is so valuable in providing a richer understanding of the Wajarri relationship that it was strongly recommended to all Council attendees and SKAO executive leadership.

Visiting the SKA-Low site

Delegates were also treated to a one-day site visit the day before Council. For some it was their first time travelling to the Australian outback, providing an invaluable understanding of the remoteness of the site and the environmental conditions, as well as the beauty of Wajarri Country. [...]

BELOW: *Council members stand in front of the AAVS3 prototype station at Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory.*

[...] The guests toured the SKA precursor telescopes ASKAP and MWA, the recently opened SKAO "fly camp", SKA-Low construction sites including the core and AA0.5 (which will comprise the first six stations of the telescope), and the SKA-Low prototype antennas AAVS2 and AAVS3.

For those who had been to the site before, the visit was a chance to see the significant progress that has been made since the Indigenous Land Use Agreement was approved and SKAO site license was signed, which preceded events to officially launch on-site construction activities in Australia and South Africa in December 2022.

Supercomputer visit

The SKAO Council visit was rounded out by a visit to the Pawsey Supercomputing Research Centre, where the SKA-Low telescope data processing and storage will be hosted. Pawsey Director Mark Stickells spoke about the centre's capabilities, including their new supercomputer Setonix which was recently ranked the fourth greenest supercomputer in the world.

ABOVE: *Prof. Phil Diamond contributes to a collaborative artwork piece between SKAO Council members and Wajarri woman Susan Merry.*

Three-quarters of contracts now awarded to deliver SKA telescopes

BY MATTHEW TAYLOR (SKAO)

Creating an airstrip, laying an 800 km dark fibre network, and cryogenically cooling key array components are among recent contracts awarded for the SKA telescopes

Contracts worth a total €130m have been agreed since July to deliver infrastructure and technologies for SKA-Mid and SKA-Low, and include important works being undertaken by local contractors.

In the Murchison, Western Australia's Central Earthmoving Company Pty Ltd, also known as Centrals, will build a main road from the Central Processing Facility to the public road network along an alignment that minimises disturbance to heritage zones.

Centrals will also build an emergency airstrip that will meet the requirements of Australia's famous Royal Flying Doctor Service, complementing a separate contract awarded to St John Ambulance WA for providing on-site emergency medical care.

In the Karoo, pan-African digital infrastructure experts, Liquid Intelligent Technologies, will design, build and operate an 800 km underground dark fibre link between Beaufort West and Cape Town to transmit the 20 Tb per second live data stream coming from the SKA-Mid telescope for correlation.

Also at the SKA-Mid site, Qamcom Research and Technology founded by researchers at Sweden's Chalmers University of Technology will provide Single Pixel Feed (SPF) receivers for the SKA-Mid dishes to digitise radio frequency output for onward transfer to the central signal processor.

A number of further contracts concerning the SKA-Mid receivers have been awarded, including Oxford Cryosystems Ltd providing cryogenic cooling technologies on one of the SPF bands.

Elsewhere, South Africa's Emcom wireless will install an emergency low band VHF digital mobile system across the SKA-Mid telescope's core and spiral arms, and Perth-based AVI will deliver SMART boxes providing power to SKA-Low's antennas (see page 11).

SKAO Head of Procurement Services, Ian Hastings, said: "The pace of contract awards in the past few months reflects the hard work and diligence within the SKAO and our tenderers.

"Particularly encouraging is the work that is being undertaken by, or subcontracted to, local and Indigenous-owned firms, and the fact that our partners have enthusiastically come along on our ambition to hire as many local and Wajarri people as possible to work on the project.

"This and the number of international awards illustrates both the truly global nature of the SKAO and our strong local anchoring within our neighbouring communities, and takes us another step closer to seeing dishes and antennas rising in the Karoo and Murchison."

SKAO and Shanghai strengthen ties

BY MATTHEW TAYLOR (SKAO)

Shanghai's Vice Mayor Duo Liu led a delegation to SKAO HQ in October as part of a visit that underscored the Observatory's strong relationship with the city.

During the visit the SKAO signed a memorandum of understanding formalising ties with the Shanghai Astronomical Observatory (SHAO), which developed the first SKA Regional Centre (SRC) prototype and hosts annual Chinese SKA Summer Schools.

"This marks an important milestone in collaborations between the SKAO and SHAO," said Prof. Zhiqiang Shen, Director of SHAO. "The China SKA Regional Centre team has made progress establishing the first prototype SRC and co-hosting the 2019 SKA Engineering Meeting, contributing greatly to scientific operations of precursor telescopes and prototyping the SRC Network."

During a tour of the HQ, the 16-strong delegation got a close-up look at an SKA-Mid dish panel: an example of one of the 66 slightly concave triangular pieces, each weighing 45 kg with sides measuring 3 m, that will tessellate together to form a complete 15-metre-wide SKA-Mid dish.

The panels are built by the 54th Research Institute of China Electronics Technology Group Corporation (CETC54) in Shijiazhuang, Hebei.

The delegates included Prof. Tao An, head of the China SRC team, who gave an update on current activities.

"Currently the China SRC team is focusing on working with our international partners to prepare the SRC Network, so that it is ready to support the testing and verification of data from the partial SKA telescope arrays as they are rolled out," he said. "We're also conducting outreach and education like SKA summer schools and data processing workshops to train the next generation of SKA scientists."

BELOW: *Prof. Zhiqiang Shen (right), Director of the Shanghai Astronomical Observatory, signs the MoU with Director of the SKAO D-G's Office, Simon Berry (left) in the SKAO Headquarters' Council Chamber.*

SKAO publishes 2022 annual report

BY CASSANDRA CAVALLARO (SKAO)

The SKA Observatory's 2022 Annual Report has been released, charting a year of significant progress across the Observatory that culminated in the start of on-site construction in Australia and South Africa.

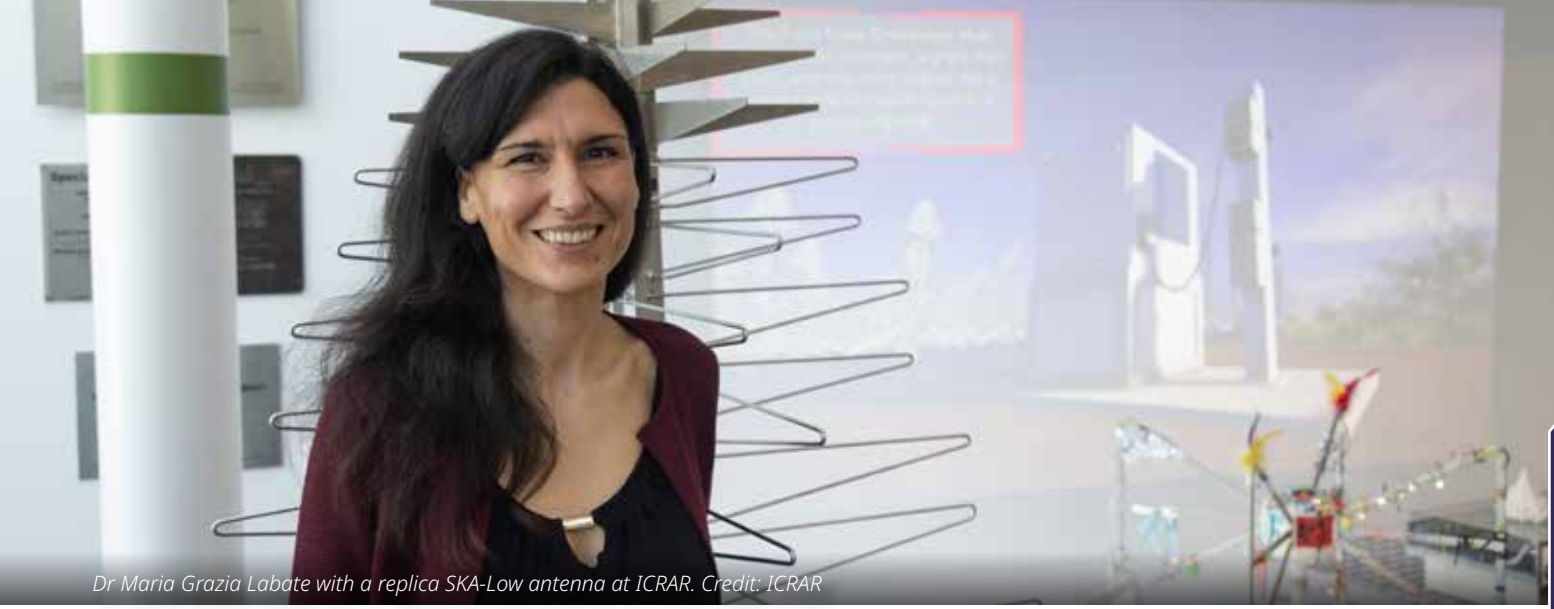
The 100-page publication highlights many major developments in 2022, including the Observatory's growing membership, expanding presence in its telescope host countries, and a huge push on the procurement front that saw 46 contracts signed by the end of the year. This amounted to approximately €470m committed since the start of construction activities in July 2021.

"Despite the geopolitical instability and macroeconomic uncertainty, the performance described in this report attests that the SKAO has remained strong and committed in the pursuit of its goals, working hard through its Council and members," said SKAO Council Chair Dr Catherine Cesarsky.

Highlights of the year included:

- Switzerland joining the SKAO as its eighth member state, with both France and Germany beginning the formal processes to become members.
- The signing of key agreements with partner organisations CSIRO and SARAO in the telescope host countries, and the establishment of an interim Engineering Operations Centre in Australia and Science Operations Centre in South Africa.
- A growth in membership of the SKA Science Working Groups, with 1,150 astronomers from all over the world involved in the 14 groups during 2022, higher than any previous year.
- The SKAO's growing role in advocating for astronomy on the international stage, as permanent observer at the UN's Committee on the Peaceful Uses of Outer Space, and a co-host of the IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference.

SKAO Director-General Prof. Philip Diamond said: "The SKAO's unwavering commitment to fostering international collaboration in these uncertain and unstable times, pushing the boundaries of scientific discovery, remains steadfast as we continue to advance towards the construction and operation of the world's largest and most sensitive radio telescopes."



Dr Maria Grazia Labate with a replica SKA-Low antenna at ICRAR. Credit: ICRAR

Sharing experiences with the next generation of STEM

BY SEBASTIAN NEUWEILER (SKAO)

After being awarded a Visiting Fellowship for Senior Women+ in Astronomy with the International Centre for Radio Astronomy Research (ICRAR), SKA-Low Telescope Engineer Dr Maria Grazia Labate has emphasised gender equality to the next generation of STEM in Australia.

The fellowship aims to provide an opportunity for senior women and gender minorities working as astronomers, engineers and data scientists within astronomy to visit ICRAR in Perth and interact with early-career researchers and graduate students.

"STEM is a wonderful and challenging environment, where collaboration and diversity are essential to develop new ideas which will lead us to amazing discoveries."

DR MARIA GRAZIA LABATE, SKA-LOW TELESCOPE ENGINEER

Dr Labate has a wealth of knowledge to share. After receiving a master's degree in telecommunication engineering, she worked as a system integration and technology analyst for telecommunication companies. She received a PhD in electronic engineering and worked for aerospace and defence companies as an antenna and phased-array designer, both for satellites and radars, before joining the SKAO in 2013.

It is this extensive experience that Dr Labate drew upon when she delivered a science seminar and diversity workshop as part of her fellowship. She spent time with students and researchers at the University of Western Australia and Curtin University – joint venture partners of ICRAR – discussing science and engineering, work-life balance, and gender equality in science, technology, engineering, and mathematics (STEM).

"Studying and working in a male-dominated environment can pose many challenges, which can vary depending on the people you meet, the university or organisation you work for, the culture you are in and from, your personality and your background," she said.

"In my experience and speaking with my female colleagues, I saw how many challenges are common and how, sooner or later, you are forced to face unpleasant behaviours and must decide how to deal with them. At the SKAO there is a strong commitment to diversity and inclusion which is very important, because reinforcing these values from the top then feeds down into everyday interactions.

"STEM is a wonderful and challenging environment, where collaboration and diversity are essential to develop new ideas which will lead us to amazing discoveries. I see it as part of our job to defend these values, so I'm honoured to be part of the ICRAR fellowship, working together with researchers, graduate students and staff towards a better and more equitable world, starting from our study and work environment."

Anton Binneman, Science Engagement Manager at SARAO, wows learners with space science facts.

ABOVE: *Representatives of South African National Parks explain that nature conservation offers a wide variety of career paths.*

Bringing space science down to earth in South Africa

BY ALMA VIVIERS (SKAO)

Did you know? A group of radio astronomers in Australia developed technology that helps Wi-Fi signals travel quickly and clearly. Without them, our internet would be painfully slow. This is just one of the facts shared during National Science Week in South Africa, evidencing the relevance of radio astronomy to people's everyday lives.

The annual initiative of the Department of Science and Innovation celebrates science, technology, engineering, mathematics, and innovation (known collectively as STEMI), with various agencies and institutions in these sectors conducting outreach activities under the science week umbrella. This year's theme, "transforming lives through evidence-based science", focused on science literacy.

The SKA-Mid team joined the South African Radio Astronomy Observatory (SARAO) science engagement team, and representatives from South African National Parks and Sol Plaatje University for a whirlwind tour of the four towns surrounding the SKA-Mid site in the Northern Cape during the event from 31 July to 4 August.

The team had a three-pronged approach to the week's engagements:

1. School visits sought to pique interest in careers in STEMI fields. SARAO's School Scholarship Programme supports students to continue in maths and science at a secondary school level, with a view to supporting high-achieving students with undergraduate scholarships to the Sol Plaatje and other universities. Hendrik Malgas, park manager of the MeerKAT National Park where SKA-Mid is being built, also shared the various career opportunities that conserving the natural heritage, and maintaining dark and quiet skies holds.
2. The SKA-Mid and SARAO teams also used this opportunity to arrange community meetings in Brandvlei, Vanwyksvlei, Williston and Carnarvon. During these meetings, SARAO Science Engagement Manager Anton Binneman explained to residents how a project like the SKA fits into the national economic shift from an extractive resource economy to a knowledge economy. He also highlighted how fields like astronomy not only contribute to science but also everyday applications that improve lives and overall help progress the United Nations Sustainable Development Goals.
3. Every evening, the Carnarvon Astro-Guides (read more on page 7) led stargazing sessions that brought to life the awe and wonders of the night sky, bridging the gap between ancient knowledge and contemporary scientific inquiry through storytelling.

"Outreach activities like those during National Science Week are not just about bringing the mysteries of space closer to home; they're about connecting our everyday lives to the vast cosmos. They show us that science isn't confined to laboratories and observatories; it's part of our world, shaping our future and improving how we live," said Binneman.

‘SKA-Low down’ for National Science Week in Australia

BY LIZ WILLIAMS (SKAO)

Each August, Australia holds National Science Week to encourage Australians of all ages to engage with science and promote science endeavours to the public. More than 1,000 events are held across the country and more than one million people participate in National Science Week activities.

This year, the SKAO partnered with CSIRO, Australia’s national science agency, and the Museum of Geraldton to host a community event in Geraldton – a Q&A-style panel with experts from the SKAO and CSIRO.

Geraldton is the “gateway” to the SKA-Low telescope as the nearest large regional town to the observatory site, and location of both the SKA-Low Engineering Operations Centre and CSIRO observatory support facility. Held at the Museum of Geraldton, around 60 people attended the event titled *What’s the lowdown on the SKA-Low?* It was an opportunity to talk with the local community about the SKA Observatory and the SKA project, and update them on the latest news now that construction is underway.

SKA-Low Telescope Director Dr Sarah Pearce and Procurement Specialist Nicole Robins were joined on the panel by CSIRO Space and Astronomy Director Dr Douglas Bock and MC Chris Brayton from the CSIRO observatory site entity team. The event included a presentation from Wajarri Yamaji representative Des Mongoo about how the Wajarri people – the Traditional Owners and native title holders of the site where the SKA-Low telescope is being built – are engaging with the SKA project in Australia.

The panel answered questions from the community that ranged from radio astronomy and how it works, to what makes the Murchison region one of the best places on Earth for radio astronomy, how the SKAO and CSIRO intend to engage in outreach with the Geraldton community, and what the plans are for local jobs across the lifetime of the project.

The evening also included stargazing with local astro-photographer Ken Lawson, and an unexpected sighting of the International Space Station traversing the sky!

BELOW: *Wajarri Yamaji representative Des Mongoo speaks to the audience at the National Science Week event in Geraldton*

Two minutes with... Prof. Fred Watson

Prof. Fred Watson is the Australian government's Astronomer-at-Large, and is well known for his award-winning radio and TV broadcasts, books, music, and Space Nuts podcast. He made his first visit to SKAO HQ in the UK in September.

Welcome to our HQ, Fred! Being based in an SKAO telescope host country, what do you see as the particular benefits for Australia and South Africa, as construction progresses?

Certainly science outreach is something that draws strength from the presence of a major facility on home soil. It's easier to excite the public's enthusiasm for an establishment they can call their own than one on the other side of the world – perhaps even more so when it has multinational status. In general, the benefits for host countries extend further, ranging from opportunities in construction and operation to greater international kudos. In the case of the SKAO, there's the added dimension of relations with First Nations custodians in the host countries, broadening the story in a very valuable direction.

As a science communicator, what do you think the astronomy community can do to further interest in STEM subjects?

It is tomorrow's scientists who will be the main beneficiaries of the SKAO. My advice would be to view STEM outreach as an essential attribute when budgets are being allocated – and be generous!

Of course you're also an astronomer, so what scientific discoveries do you most look forward to the SKAO delivering?

The ones that will win Nobel Prizes! There are many possibilities in the SKAO's playbook, but mapping hydrogen in the Universe's dark ages is one, and probing the limits of general relativity is another – especially if it reveals hints of new physics.

You're attending the IAU Symposium on Astronomy and Satellite Constellations (see page 44). Do you see progress on maintaining dark and quiet skies for astronomy?

I'm encouraged by the goodwill that has emerged on all sides over the past year, and I believe there is cause for optimism. Ground-based observational astronomy will never be the same as it was before the constellation era, but with mitigation strategies currently being developed, it will continue to thrive.

Growing interest in SKA project in Poland

BY MATHIEU ISIDRO (SKAO)

Over the past few months, several engagement opportunities have seen new ties develop between the SKAO and Poland, supported by an enthusiastic Polish grass-roots effort to explore potential future participation in the Observatory.

This year's European Astronomical Society meeting, held in Krakow in July, provided an ideal opportunity to brief the assembled Polish astronomical community on the status of the SKA Observatory, its scientific community, and science operations. With support from the Polish Astronomical Society, the Observatory organised a town hall open to all members of the Polish astronomical community.

Interventions by SKAO Head of International Relations Thijs Geurts, Project Scientist Dr Tyler Bourke, Head of Science Operations Dr Shari Breen, and Electronic Engineer Bartosz Idzkowski generated plenty of interest from the full room. Deputy Head of the National Centre for Nuclear Research Dr Agnieszka Pollo moderated the session, and has since visited the SKAO Global Headquarters for further discussions.

In September, the Observatory was invited to host a follow-up session at the Polish national astronomy meeting in Toruń. Dr Agnieszka Slowikowska, the new director of Joint Institute for VLBI ERIC (JIVE), organised and moderated the session to discuss the prospects of Poland developing closer links with the SKAO.

The promising discussions are the start of an effort in Poland to explore closer links with the SKAO. This effort would see the creation of a national consortium, with a view towards future membership of the Observatory. Poland's scientific interests in radio astronomy are many, with existing expertise and participation in low-frequency radio astronomy through hosting LOFAR stations, and its participation in European VLBI observations through JIVE. Poland also participates in SALT, the South African Large Telescope, where it holds a significant share.

BELOW: *SKAO town hall for the Polish astronomical community at the Polish national astronomy meeting in Toruń earlier this year.*

Elizabethfontein children performed three dances as a thank-you, including the traditional "riel" dance.

South African school kids 'reach for stars' at HQ

BY ANIM VAN WYK (SKAO)

Staff at SKAO HQ were given a "riel" treat during a visit by a group of South African students.

Eight pupils aged nine to 12 from the Elizabethfontein Primary School in South Africa's Cederberg region showcased a riel dance – a traditional celebratory dance in South africa – in the shadow of the Lovell Telescope in June.

The performance had echoes of the SKA-Mid construction commencement ceremony in December last year, when a sunset riel dance was performed by the Kareeberg Cultural Association with MeerKAT's dishes silhouetted beyond.

The children were visiting due to the Elizabethfontein Primary School being twinned with the primary school in Goostrey, SKAO HQ's neighbouring village.

During their visit, Afrikaans-speaking colleagues were able to explain to the four boys and four girls about how the electromagnetic spectrum and radio telescopes work.

There was also a tour of Jodrell Bank's First Light Pavilion visitor attraction and a viewing of a planetarium film narrated by the Lord of the Rings actor, Andy Serkis.

ABOVE: *Mariëtte Kotzé and Annatjie Dames take receipt of a telescope gifted by the SKAO to the learners of Elizabethfontein school. The handover took place outside the Artscape theatre in Cape Town where the "riel" dance team were competing in a regional schools' talent competition. Credit: Elizabethfontein Primary School*

Elsewhere, SKAO Product Assurance Engineer Monique Marinus, who is from a town in South Africa familiar to the children, recorded a message about how she landed a job at the SKAO; helping the children get inspired in pursuing careers in STEM.

To further their enthusiasm, the SKAO gifted the Elizabethfontein Primary School an optical telescope and a microscope to use in their science classes.

"Today felt like home with Afrikaans in Goostrey," said Elizabethfontein teacher Mariëtte Kotzé.

"Our motto at school is 'reach for the stars' and today we were the stars."

Sharmila relaxing on a walk at Langebaan lagoon.

Dr Sharmila Goedhart – SKA-Mid Head of Science Operations

One might say South Africa's star has risen quickly in astronomy. Huge investment and home-grown innovation led to the development of the world-class MeerKAT radio telescope, inaugurated in 2018, and a new generation of scientists and engineers has been inspired by the country's successful bid to become an SKAO host country.

Among them is Dr Sharmila Goedhart, appointed as the head of science operations for the SKA-Mid telescope earlier this year. She simultaneously holds the same role for MeerKAT, and will oversee its integration into SKA-Mid. Sharmila spoke to us about the complexities of that task, national pride over the SKA project, and the many creative outlets that fill her spare time.

Let's start at the beginning, Sharmila. Where did you grow up and what kind of things did you enjoy as a youngster?

I was born in Paarl, South Africa, and spent my childhood in various locations in Cape Town. I was a rather introverted child, and terribly clumsy and uncoordinated, so I did not do anything sporty. I preferred to spend my spare time with my nose in a book, preferably under a tree somewhere. I also really enjoyed arts and crafts, but my access to supplies was limited (cue my later obsession with art and craft supplies). I remember sewing little dolls clothes by hand using scraps from my mother's sewing, and then trading them for the fancy Barbie accessories that my parents couldn't buy me.

ABOVE: *Sharmila with her husband, Andrew, on their wedding day.*

When did you start to get interested in astronomy – what inspired you?

It was the books. Reading was, and is, my passion. I refused to go anywhere without a book. The city of Cape Town has a mobile library service to areas that do not have a public library. I used to have to walk a long way home from school, and I knew every place that the library bus parked on different days. I was only allowed to take out three books at a time from the children's section, and would finish them in less than a week. I still feel great joy whenever I see those library buses, and very glad that they are still operating in the city.

I loved maths and science at school and my teachers nurtured these interests. I gradually started getting interested in science fiction and fantasy, then came across the works of Isaac Asimov and Arthur C. Clarke. Then I started reading non-fiction works, including Cosmos by Carl Sagan. There was also a TV series about astronomers, around the late 80s/early 90s, that I found really exciting and inspiring.

How did that lead to a career in this field?

I managed to get a full costs bursary to the University of Cape Town (UCT), which enabled me to study maths and physics and whatever astronomy courses were on offer at the time. People kept telling me that I would not find a job as an astronomer, but people also kept saying that if you had these skills you could do anything. So I just went on my way, bugging my astronomy professors for chances to look through a telescope.

My first trip to the South African Astronomy Observatory at Sutherland during the holidays just cemented my love for astronomy. For my honours degree I did my research project in astronomy. It was an optical project that involved running up to the top of a ladder every few minutes to change filters on the 0.5 m telescope and manually centre the target on the crosshairs. I think today's health and safety practitioners would be horrified! I was all alone in the telescope dome, and there was just a call at midnight from the observer at the 1.9 m telescope every night to make sure everyone else was still OK.

That project still didn't put me off, so I did my master's degree in astronomy at Potchefstroom University (now Northwest University), and continued on to do my PhD while based at the Hartebeesthoek Radio Astronomy Observatory (HartRAO). I found that I really enjoy the technical aspects of observations, and getting to know my instruments really well.

When did the SKA project enter the picture?

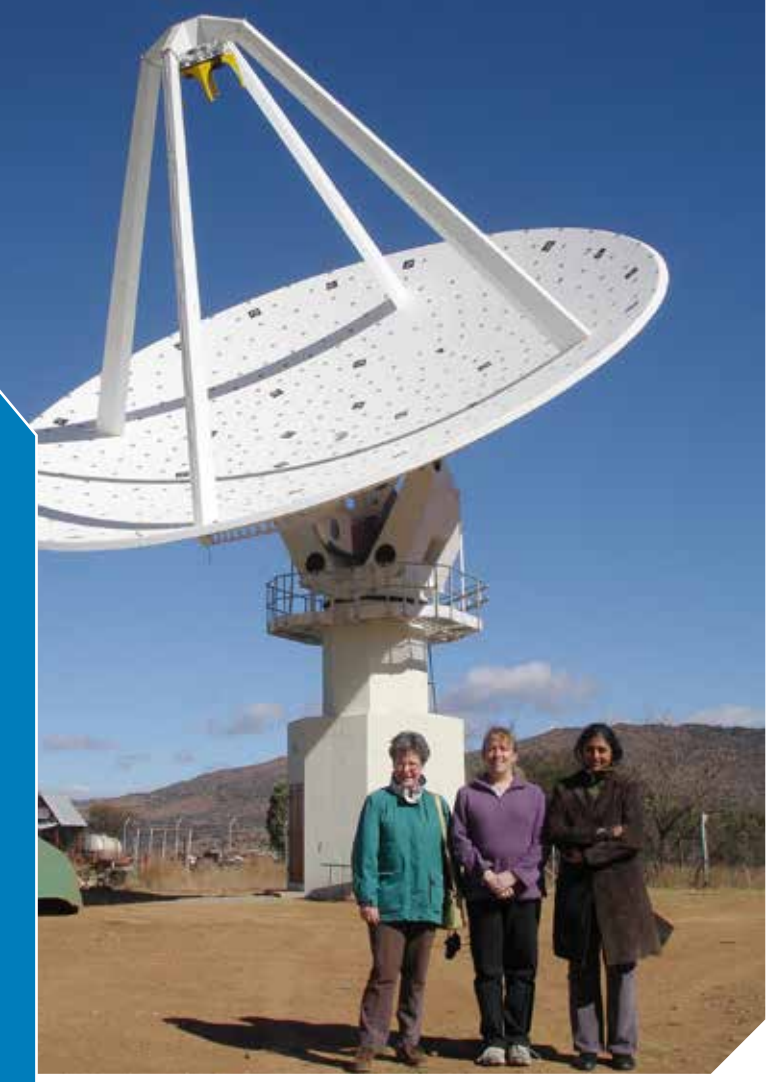
After I completed my PhD, I spent six months in Bonn, Germany at the Max Planck Institute for Radio Astronomy, learning more about interferometry and sub-millimetre observing in particular. I returned to HartRAO as a staff astronomer, but my eye was very quickly caught by what was then called the SKA Africa project, since they were

ABOVE: *Sharmila at the KAT-7 telescope, a MeerKAT precursor.*

building the first prototype dish for the Karoo Array Telescope, the 15 m eXperimental Development Model, known as XDM, right outside my office. I joined the project in 2008 and moved back to Cape Town. I was the very first member of the science commissioning and operations team. I really did not know much at that point, so I visited ASTRON in the Netherlands to hang out with the Westerbork Synthesis Radio Telescope operators. I learned a lot!

I learned even more when we started integrating and commissioning the KAT-7 telescope, which was the prototype/pathfinder for MeerKAT. It was very hands on. We'd spend up to a week at the time on site, operating out of a 12 m container converted into an office. I miss those days – the dark skies, silence and solitude – but I don't miss the dust, heat and spiders.

I gradually grew in knowledge and experience, working my way up to senior commissioning scientist with the South African Radio Astronomy Observatory, then manager of the science commissioning team, and eventually becoming head of science operations and commissioning for MeerKAT.



ABOVE: *Sharmila (right) with Prof. Dame Jocelyn Bell Burnell (left) and Sarah Buchner (centre).*

And now you're head of science operations for SKA-Mid as well! Talk us through what that involves day-to-day.

Currently it's pretty busy and varied. I am in close communication with science operations colleagues in the UK and Australia, understanding where we are and what needs to be done. I am using my 15 years of experience with KAT-7 and MeerKAT to inform science operations planning and giving input to the various software teams working on the control and monitoring systems and science user tools. I am also tasked with building the science operations team in South Africa. It's a really exciting time, being able to have influence in the way the Observatory grows and evolves over the coming years. Excitement continues to rise as more and more components for the telescope are arriving. I love learning and doing new things – routine bores me after a while and I don't foresee being bored here for a very long time!

What kind of lessons did you learn from commissioning MeerKAT, and how are those helping in your current role?

In retrospect, it would have been useful to start working on science operations tools and making things accessible to the users before MeerKAT construction was complete. That would have made the last five years less tough, with a faster delivery of the data to the community. Luckily our users have been very understanding and love the quality of the data. I have worked on almost all aspects of the telescope during commissioning, so I have a deep knowledge of the entire signal chain, the sort of things that can go wrong and how to identify them. There are extremely valuable lessons that I can bring to the SKAO during this critical phase, where new tools, policies and procedures are being developed in Science Operations.

How are you preparing for MeerKAT integration into SKA-Mid, and what kind of challenges are involved?

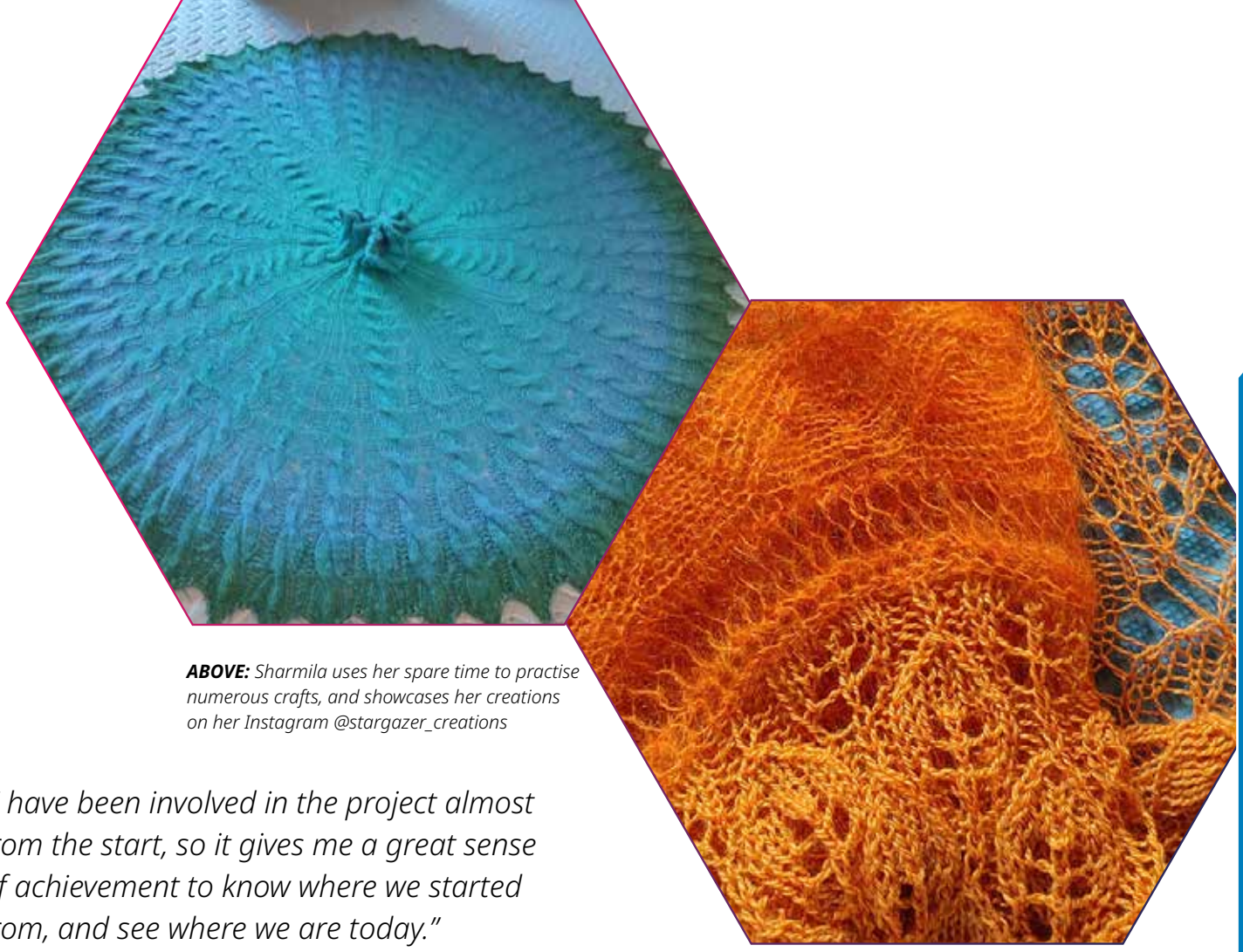
Right now I am still leading and supporting the MeerKAT science operations team in addition to my role with the SKAO. We have a joint operations agreement with SARAO, so the SKA-Mid operations scientists will also be working on MeerKAT. MeerKAT is also in the process of expanding (MeerKAT Extension Project) so this will be an ideal opportunity to test and refine our commissioning and science verification procedures. It is going to be challenging to balance the needs of the two telescopes, particularly ensuring that construction activities do not interfere too much with MeerKAT's ability to take high quality data, unaffected by radio frequency interference (RFI). We're putting every measure in place to mitigate any potential disruption so that we can work in parallel, and we'll refine the plans as needed to ensure MeerKAT can continue to deliver high quality science. That's why it's so important for me and the wider team to be working across both telescopes.

Let's talk about your own science interests. What particularly fascinates you and what are you hoping to discover when the SKA telescopes come online?

Helping others achieve their scientific goals, while very rewarding, has left very little time for my own research. My primary field of study was in how the most massive stars form, and specifically using emission from astrophysical masers to understand the environment of these stars [astrophysical masers occur when molecules are stimulated to produce microwave light; they often occur in star-forming regions]. During my PhD, I discovered that a fraction of these vary in an extremely regular manner and we've been trying to figure out what that means ever since. It could be an indication of a binary system, or rotating accretion disks, or other ever more complicated scenarios. It's been interesting seeing the various hypotheses over the years, and other supporting observations that are now emerging. As I suspected, there are multiple causes of the variations in different star forming regions. The SKA telescopes will be able to examine these regions in unprecedented resolution and sensitivity, so I'm hoping we finally figure out what's going on there.

What does it mean for you to be part of Team SKA as construction begins, particularly as a South African?

I am thrilled and proud. I have been involved in the project almost from the start, so it gives me a great sense of achievement to know where we started from, and see where we are today.



ABOVE: *Sharmila uses her spare time to practise numerous crafts, and showcases her creations on her Instagram @stargazer_creations*

> *"I have been involved in the project almost from the start, so it gives me a great sense of achievement to know where we started from, and see where we are today."*
>
> **DR SHARMILA GOEDHART, SKA-MID HEAD OF SCIENCE OPERATIONS**

Do you feel that the SKAO and its partners are already having an impact, both within and beyond science?

The radio astronomy community in South Africa has grown enormously. I was the first PhD in probably about 10 years, and there were about 10 radio astronomers in the country at the time, depending on how you count them. These days I am constantly seeing people that I don't know. And it's been wonderful seeing the graduates of the SARAO human capital development programme becoming established and influential researchers. It is indeed an iconic project in South Africa, proving that we can build and operate a world-class scientific instrument and people are immensely proud. It's also a great example of skills transfer; many of the graduates of the human capital development programme do not stay in astronomy, but go into other fields, and into industry, enhancing our ability to deliver on high-tech projects.

If you could give advice to your younger self about getting into astronomy, or STEM in general, what would it be?

Believe in yourself and stand up for yourself. It was pretty tough as a young woman of colour at times, being dismissed and ignored. The only way through is to carry on, become successful and show the doubters and haters that they were wrong. Luckily for me, all through my studies and career, there have been people that have seen my potential and helped me along the way. I try to do the same for every young person I work with.

What do you like to do outside of work to help you to wind down?

I have lots of hobbies. The spare bedroom (amongst other places) is mostly full of my craft supplies. I like creating fine, delicate things and learning to master challenging techniques. I have made silver jewellery, in particular filigree. I started learning to facet gemstones but that's been challenging and been on hold for a few years. Currently I am primarily working on fibre arts. I started with knitting, then I started dyeing my own wool, because it was cheaper and I could get exactly what I wanted. Then I learned to spin because I could not find the type of yarn I wanted for my lace knitting, and now I'm learning to weave because I can't knit up all the yarn I have spun. I'm a member of the Cape Guild of Weavers and preparing for our exhibition at Kirstenbosch Botanical Gardens next year. I do occasionally attempt some drawing and painting, but there are just not enough hours in the day or night to do all the things.

Experts gather to address impact of satellite constellations on astronomy

BY MATHIEU ISIDRO (SKAO, IAU CPS COMMUNICATIONS LEAD)

An IAU symposium sponsored by the SKAO brought together for the first time astronomers, legal experts, Indigenous voices, industry, and government representatives to discuss the impact of large satellite constellations on astronomy.

Some 250 people met in La Palma, Spain and online in October to attend the meeting organised under the umbrella of the International Astronomical Union, the IAU.

"The IAU is very concerned about keeping the skies suitable for astronomical research, and also for the cultural good of humanity," said IAU President-Elect Prof. Willy Benz who attended the event. "These satellite launches have lasting consequences, and it's the accumulation of satellites that creates a problem."

About 80 speakers and experts in different fields addressed a wide range of topics related to satellites' impact on astronomy and the skies, from Indigenous cultural perspectives, to satellite observation campaigns and the development of mitigation software by astronomers, regulatory issues and legal frameworks in different countries, industry efforts to mitigate their impact, and international decision-making.

Several representatives from across SKAO's technical, legal, and communication departments took part in the meeting to discuss the Observatory's work in this area, for example at the United Nations and its recent detections of satellites at low frequencies using the SKA pathfinder telescope LOFAR in the Netherlands and the SKA precursor telescope MWA in Australia.

The last day of the meeting also saw the launch of a "Group of Friends of the Dark and Quiet Sky for Science and Society", bringing together representatives from national delegations at the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS). Launched by the delegations of Chile and Spain, the informal group seeks to promote awareness of the issue, review and support the development of best practices, and progress discussions of the topic at COPUOS.

So are experts positive about solving this fast-growing issue? "There's reason enough to be optimistic," declared Mila Francisco, Chilean representative to the United Nations Office in Vienna, which includes COPUOS. "The astronomical community have been able to move a lot of governments, and this isn't easy."

"Work is being done, and measurable progress is being made. And so no matter how much is ahead of us, we need to continue, and we'll get there because we have to," concluded Prof. Benz.

The meeting was hosted by the Institute of Astrophysics of the Canary Islands (IAC), with support from the IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (IAU CPS). Proceedings are being prepared for publication.

LEFT: *IAU symposium attendees arriving at La Palma, Spain for the conference. Credit: SKAO*

A two-and-a-half hour exposure illustrating space debris and satellite constellation orbits, taken at night at Pentre Ifan in Wales, a neolithic tomb close to where the stone for Stonehenge is believed to have been quarried. Copyright: Max Alexander

Photographer explores satellite and space debris response

BY SKAO

SKAO HQ welcomed renowned space photographer Max Alexander as his new exhibition, Our Fragile Space, opened at the neighbouring Jodrell Bank Observatory.

Our Fragile Space focuses on the growing issue of space debris and the impact of satellite constellations on astronomy.

It combines artistic photography, reportage and portraiture to demonstrate the fragility of space, highlight the increasing threat of space debris to our environment and to centre the people and initiatives trying to do something about it.

The SKAO's sponsorship of the exhibition reflects the Observatory's work with the International Astronomical Union's (IAU) Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (CPS).

Alongside co-host the US National Science Foundation's NOIRLab the SKAO helps coordinate collaborative international efforts to mitigate the impact of satellite constellations on ground-based optical and radio astronomy – a theme highlighted through Alexander's photographs.

The exhibition has toured the world and was previously on display at the United Nations in Vienna.

Images include a two-and-a-half hour exposure illustrating space debris and satellite constellation orbits, taken at night at Pentre Ifan in Wales, a neolithic tomb close to where the stone for Stonehenge is believed to have been quarried (pictured).

There are also photographs of space debris that have returned to Earth, including fuel tanks and rocket bodies, as well as an image of NASA scientist Donald Kessler standing over a table of falling dominoes to represent his "Kessler syndrome" theory of satellite collision chain reaction.

Alexander said: "It's a project about how crowded space is becoming, with satellites and space debris that is really becoming part of the Earth's environment, or near space. These new satellite mega-constellations which are giving internet coverage around the world are only about 500 km from us, so no distance at all.

"Protecting the near-space environment is in everyone's interest, and this new field of space, environmentalism and stewardship of this environment is really important."

PAERI conference heading to Switzerland

BY MATHIEU ISIDRO (SKAO, PAERI WORKING GROUP CHAIR)

The fifth edition of the Public Awareness and Engagement with Research Infrastructures conference, or PAERI for short, will be hosted by SKACH, the Swiss consortium for the SKAO, near Lausanne in Switzerland from 27-29 November 2024.

Centred around the theme "science communication across borders", the conference will bring together science communication practitioners from across European research facilities and beyond to discuss ways to communicate science across borders both physical and virtual – whether this might be language, education, technology, geography, demographics, and more.

Egyptian physicist Dr Gihan Kamel will deliver the keynote address, speaking about her career and science communication and diplomacy in the Middle East through the SESAME project (Synchrotron-Light for Experimental Science and Applications in the Middle East).

Hosted by SKACH at Le Cube, a brand-new modern cultural event space in Morges, just outside Lausanne, the PAERI'24 hybrid conference will see two days of talks and workshops on the public communication activities of research infrastructures, followed by a visit to CERN, where a new science engagement centre has just been inaugurated.

The previous edition was held at the SKAO Global Headquarters in July 2022.

Watch: SKAO hosts international science communication meeting PARI

Visitors flock to family outreach events in the UK

BY DR HILARY KAY (THE UNIVERSITY OF MANCHESTER)

Recent months have provided exciting opportunities for SKA-themed outreach in the UK, with the UKRI Science and Technology Facilities Council (STFC) welcoming visitors to its sites for open days, and the Bluedot festival taking place again at Jodrell Bank.

In July, festival-goers braved the typically fickle British summer weather to take part in a bumper weekend of fun-filled activities at Bluedot, a science, music and art festival which takes place next door to SKAO HQ. As ever, volunteers from the HQ and The University of Manchester inspired visitors, providing hands-on activities and the opportunity to take part in some live radio astronomy observing. Across the festival, visitors were also treated to engaging talks not only about the SKA telescopes and the revolutionary science they will enable, but also on the impact of large satellite constellations on facilities like the SKAO.

SKAO staff volunteering at the Bluedot festival. Credit: SKAO

July also saw Daresbury Laboratory throw open its doors to more than 5,000 visitors, showcasing the cutting-edge research funded by the STFC and raising awareness of the SKAO and the UK's role in it.

The UK Astronomy Technology Centre, based at the Royal Observatory Edinburgh, also welcomed almost 2,500 visitors to the historic site as part of the Edinburgh Doors Open event in September. Alongside activities for the younger visitors, staff explained their role in developing essential software for the SKAO and highlighted the immense scale of the project, aiming to inspire some of the next generation of astronomers and data scientists.

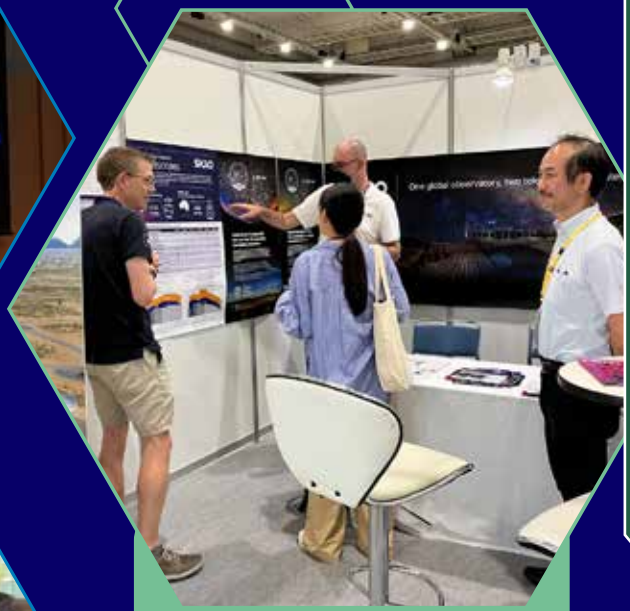
ICALEPCS

Team SKA was well represented at ICALEPCS, the International Conference on Accelerator and Large Experimental Physics Control Systems, held in Cape Town in October, with software specialists from the SKAO and partner organisations taking part.

SKAO presence at international events

URSI

The International Union of Radio Science General Assembly and Scientific Symposium (URSI GASS) took place in Sapporo, Japan, in August, where System Scientist Shin'ichiro Asayama presented an SKAO update.



APRIM

SKA-Low Head of Science Operations Dr Jimi Green and Operations Scientist Dr Jess Broderick joined SKA Japan partners including Hiroyuki Nakanishi in Koriyama for the Asia Pacific Regional IAU Meeting (APRIM) in August.

ABOVE: *Group photo of participants from the fourth Swiss SKA Days. Some 150 people attended the three-day meeting from all over Switzerland and beyond. Credit: SKACH*

Clear skies for Swiss SKA Days 2023

BY TANYA LISE PETERSEN (SKACH)

Switzerland officially joined the SKAO in January 2022 but Swiss SKA Days have been going for much longer. This year's event was held at the University of Zurich, and what a journey it was – from Zurich to Australia, South Africa and the stars!

Around 150 participants from Switzerland and the global SKA community joined together to hear presentations on everything from the research possibilities that the SKA telescopes will open up, to dark and quiet skies and the importance of sustainability in space for radio and other astronomy.

Professor Lucio Mayer, from the university's Institute for Computational Science Center for Theoretical Astrophysics and Cosmology, welcomed participants to the event, which was the seventh edition of the Swiss SKA Days.

The audience then heard from University of Zurich President Michael Schaepman, who reminded them that no fewer than 12 Nobel Prizes have been awarded to the university's scientists, including Albert Einstein who received his PhD there in 1905.

Ambassador Michael Gerber, Head of the International Programmes and Organisations Division at the State Secretariat of Science, Innovation, Research, and Education (SERI), presented Switzerland's perspective on the SKAO, including the commitment to contribute to construction and operation of infrastructure until beyond 2030 and the merging of astrophysics and computer science.

Dozens of other enthralling presentations covered subjects including efforts to foster space sustainability, the physics of the Cosmic Dawn and the Epoch of Reionisation in the SKA era, astrochemistry, and ranging deep-space missions for gravitational waves and dark matter.

Of course, it wouldn't have been a proper Swiss event without a visit to the Lindt chocolate factory just outside of Zurich, to see how the famed sweet treat is made!

The organisers wish to thank everyone who attended this year's event, and look forward to welcoming attendees again next year.

SKACH, comprising 10 Swiss institutions, is leading Switzerland's contributions to the SKAO on behalf of SERI. It will deliver contributions in five key programmes: science, data science, computing platforms and infrastructure, instrumentation, and education and public outreach.

Dutch ministerial visit to South Africa strengthens astronomical co-operation

BY LETEBELE JONES (SKAO)

A Dutch ministerial visit to South Africa took place in October, bringing together government officials, diplomats and science representatives from two SKAO member states and focusing on the astronomical ties between them.

During his address at the University of Cape Town's Department of Astronomy, the Dutch Minister of Education, Culture and Science Professor Robbert Dijkgraaf said: "Astronomy has been a leading science because it brings people together. It makes you feel small when looking at the stars but also makes us feel connected. South Africans have front-row seats with the best views of the Milky Way."

In an evening filled with astronomy talks and demonstrations, SKA-Mid Head of Science Operations Dr Sharmila Goedhart presented on the progress of the SKA-Mid telescope to date. The event also included an immersive 3D visualisation that enabled viewers to "take a step" into the Universe in the Inter-University Institute for Data Intensive Astronomy (IDIA) visualisation lab. Meanwhile, stargazing took place at the Tony Fairall Teaching Observatory, situated on the rooftop of the astronomy department's building.

The visit served to bolster the existing connections and collaborations between the Netherlands and South Africa in astronomy. It also provided opportunities for discussions and networking among a diverse group of academics, postgraduate students and members of the astronomy community, as well as the Dutch delegation and officials from South Africa's Department of Science and Innovation.

BELOW: *The Netherlands Minister of Education, Culture and Science Prof. Robbert Dijkgraaf (fourth from left) met Dutch and South African science and government representatives during the visit. Credit: Michael Hammond*

SKAO meets SXSW

BY LIZ WILLIAMS (SKAO)

In October, the SKAO hosted a panel at South by Southwest (SXSW) Sydney, a week of innovation, creativity, tech and collaboration with more than 400 sessions and 700 speakers from around the world.

It was the first time that the international creative industries festival SXSW had been held outside of its home city of Austin, Texas.

The SKAO hosted a Q&A-style panel as part of the 2050 track, focusing on long-range, big-picture thinking and projects. Called *Better, Faster, Further: Cosmic Origins and the SKAO*, it featured people from across the partnership in Australia: SKA-Low Telescope Director Dr Sarah Pearce, Wajarri Yamaji man Dwayne Mallard and Australian SKA Regional Centre Director Dr Karen Lee-Waddell.

Moderated by science communicator and Swinburne astrophysicist Prof. Alan Duffy, the one-hour panel covered a range of topics. They discussed how mega-science facilities can have a societal impact beyond astronomy for the global community; the unique partnership with the Wajarri Yamaji the SKAO and its partners have established in Australia and the lessons other countries can learn from this model; the leap in big data technologies that the project will necessitate; and how projects such as the SKA can inspire future generations into STEM careers.

The audience asked interesting and sometimes challenging questions, including how the community can engage with software development, how the SKAO will meet its commitments to sustainability and the global community, and what the unforeseen consequences of the project could be.

Dr Pearce said it was great to engage with a different audience at the event.

"It was really interesting to have the opportunity to speak with people from tech, from the media, arts, filmmakers, all of whom were at the session, who have a really different perspective on what we are doing."

BELOW: *(L-R) Dwayne Mallard, Dr Karen Lee-Waddell, Dr Sarah Pearce and Prof. Alan Duffy present at SXSW Sydney.*

Save the dates for astronomy activities in Africa 2023-2024

South Africa is gearing up to welcome the first IAU General Assembly to be held on African soil in August 2024. In the lead up, a host of exciting astronomy events are planned across the continent.

Science Forum

Under the theme *Igniting Conversations About Science – People, Partnerships, Priorities for the Decadal Plan*, the forum will focus on the role of science in society, between all stakeholders, the scientific community, government, industry and civil society at large. South Africa's Department of Science and Innovation is a co-host of the event.

When: **6-8 December 2023**
Where: **Pretoria, South Africa**

MORE INFO

MeerKAT@5 conference

With 2024 marking five years since the first MeerKAT science paper, the MeerKAT@5 conference will celebrate the telescope's achievements in the scientific, engineering, and human capacity development domains.

When: **20-23 February 2024**
Where: **Stellenbosch, South Africa**

MORE INFO

African Astronomical Society (AfAS) Annual Conference and Exhibition

Talks on education, development and outreach will feature alongside science talks, and public outreach events, at this first AfAS Annual Conference and Exhibition to be held outside South Africa.

When: **15-20 April 2024**
Where: **Marrakech, Morocco**

MORE INFO

International Astronomical Union General Assembly

For the first time in its 100+ years, the IAU General Assembly – the astronomy community's biggest event – is being held on the African continent. The SKAO and many of its partners will be represented at the event, which will also be open to the public for the first time.

When: **5-15 August 2024**
Where: **Cape Town, South Africa**

MORE INFO

SKAO in the news

CGTN

Echoes of the Skies – In a 30-minute documentary for Chinese broadcaster CGTN, filmmakers traced the history of the SKA project in South Africa and the positive impact it has had on science, education, and livelihoods.

Royal Society

The origin of the universe's oldest stars – This film showcasing the work of astrophysicist Dr. Emma Chapman relays how vital the SKA-Low telescope will be for charting the cosmic dawn of our Universe.

The Conversation

How our ancestors viewed the sky: new film explores both indigenous and modern cosmology – Learn how the makers of documentary film !Aitsa (awarded "Best of the Fest" at the Encounters Film Festival in Cape Town) transposed the star-lore of the first inhabitants of the SKA-Mid site to the big screen.

ZME Science

Satellite surge: how radio astronomy is trying to see beyond the crowded skies – SKAO Spectrum Manager Federico Di Vruno speaks about efforts to protect radio astronomy from the negative effects of mega satellite constellations.

Space.com

Electronics on world's largest radio telescope are more radio-quiet than a smartphone on the moon – Find out how the electronic devices that will power the SKA-Low telescope's antennas were designed to avoid interference with faint astronomical signals.

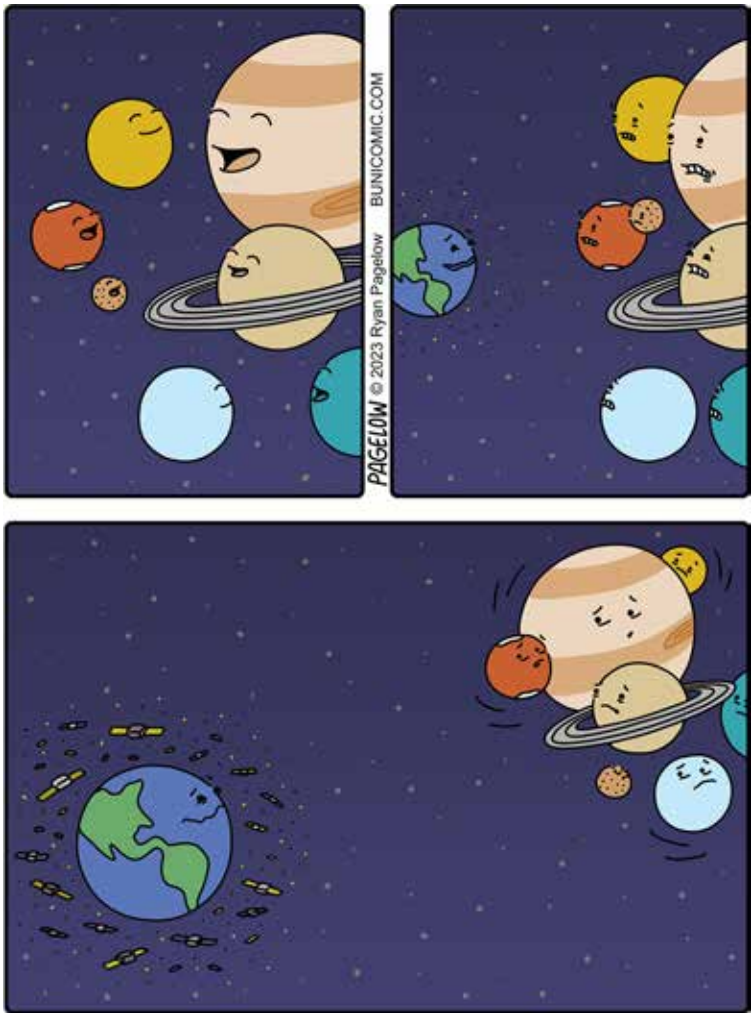
ABC

'Frenetically busy' start to work on site for Square Kilometre Array in WA's outback Murchison – Australia's public broadcaster attended a ceremony to mark the start of infrastructure work at the site of the future SKA-Low telescope. Marvel at aerial shots of the progress.

Cartoon Corner

Titled *Infection*, Ryan Pagelow's cartoon of a planet Earth sick with satellites is a timely critique of the rapidly growing number of satellites in low Earth orbit. The SKAO, through its co-hosting of the IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (CPS), and its presence on the UN Committee on the Peaceful Uses of Outer Space (COPUOS), is working to address this issue and its impact on astronomy with our international partners.

Copyright: Ryan Pagelow for bunicomic.com



Jobs

With the start of construction of the SKA telescopes, we continue to recruit staff across a number of areas at our three locations in the UK, Australia and South Africa. Some of the South Africa and Australia-based roles are employed through our partners CSIRO and SARAO. Make sure to register on our recruitment website to receive alerts.

HSE Advisor – SKA-Low Telescope

The SKA-Low HSE advisor will use a collaborative style for cultivating effective relationships with our people, contractors and other stakeholders. The HSE Advisor will be part of the SKAO's SKA-Low project team based at the Engineering Operations Centre three days a fortnight with site travel to occur every second week.

Deadline: **31/12/2023**

APPLY HERE

Deployment and Maintenance Manager – SKA-Low Telescope

The Deployment and Maintenance Manager will be integral to the delivery the SKA-Low telescope. They will lead the team responsible for assembly, deployment and integration of the telescope stations, and set up the inaugural team of technicians.

Deadline: **31/12/2023**

APPLY HERE

Senior Field Technician – SKA-Low Telescope

The Senior Field Technician will initially be focused on constructing, assembling and basic integration of the world's largest low-frequency radio telescope.

Deadline: **31/12/2023**

APPLY HERE

Field Technician – SKA-Low Telescope

The Field Technician will assist in the construction, assembly and basic integration of the world's largest low-frequency radio telescope.

Deadline: **31/12/2023**

APPLY HERE

Software Manager – Controls Systems – SKA-Low Telescope

The Software Manager is responsible for building and leading the Controls Software team for the SKA-Low telescope in Australia.

Deadline: **31/12/2023**

APPLY HERE

Celebrating our community: awards and honours

In this section we celebrate success and recognise colleagues, partners and members of the community who have received prestigious grants, awards and honours in recent months.

Dr Phil Mjwara (left), director-general of the South African Department of Science and Innovation and South African representative on the SKAO Council, received the National Research Foundation (NRF) Significant Contribution Award for his instrumental role in the development of the SKA project in South Africa, including in supporting employment opportunities, skills development, education and training.

The International Centre for Radio Astronomy Research (ICRAR) received a Gold Pleiades Award from the Astronomical Society of Australia for the institution's commitment to advancing diversity and inclusion in astronomical sciences and technology.

Dr Nichole Barry, a member of the SKAO's Epoch of Reoinisation Science Working Group, was a joint winner of the Astronomical Society of Australia's Louise Webster Prize for outstanding research by an early-career scientist, for her work with the SKA precursor Murchison Widefield Array.

Dr Rob Adam, former director of the South African Radio Astronomy Observatory (SARAO) will receive an honorary doctorate from Stellenbosch University in recognition of his substantial contribution to science, technology and society, including his instrumental roles in the completion of the MeerKAT radio telescope and in South Africa's successful bid to be a host of the SKA Observatory.

Prof. Heino Falcke, a member of the SKAO's High Energy Cosmic Particles Science Working Group, was awarded the Balzan Prize for being the first to envision imaging the immediate surroundings of a black hole, and for his leadership of the Event Horizon Telescope.

Prof. Yashwant Gupta, director of India's National Centre for Radio Astrophysics (NCRA) has been awarded the Distinguished Alumnus Award 2023 by his alma mater, the Indian Institute of Technology Kanpur, for his seminal contributions to radio astronomy.

***CONTACT* – THE SKAO'S MAGAZINE**

Published by the SKAO Communications team.

Editor: William Garnier
william.garnier@skao.int

Managing Editor: Cassandra Cavallaro
cassandra.cavallaro@skao.int

Editorial team: Mathieu Isidro, Liz Williams, Letebele Jones

Staff writers: Matthew Taylor, Sebastian Neuweiler, Alma Viviers, Anim van Wyk

Science liaison: Dr Tyler Bourke

Design: Joe Diamond, based on an original design by Carbon Creative

We welcome your contributions to *Contact*!
Get in touch with us at magazine@skao.int

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

ABOUT THE SKAO

The SKAO, formally known as the SKA Observatory, is an intergovernmental organisation composed of member states from five continents and headquartered in the UK. Its mission is to build and operate cutting-edge radio telescopes to transform our understanding of the Universe, and deliver benefits to society through global collaboration and innovation.

The SKAO recognises and acknowledges the Indigenous peoples and cultures that have traditionally lived on the lands on which our facilities are located. In Australia, we acknowledge the Wajarri Yamaji as the Traditional Owners and native title holders of Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory, the site where the SKA-Low telescope is being built.

FRONT COVER: *Nyarluwarri, the Seven Sisters. Created by Wajarri artist Tania Dudgeon.*

Aboriginal people have been studying the night sky for tens of thousands of years. The study is more than just an appreciation of the beauty of the Milky Way, it is a scientific study. The environmental knowledge and information contained within the stars is directly connected to what is happening on Country, in the sea and within culture.

Nyarluwarri (Seven Sisters) is in the Wajarri evening sky around Ngarlbugala (summertime).

Tania Dudgeon is a first cousin to Olive (Egan) Boddington, whose story is depicted in the painting (with permission from Leonie Boddington, Olive's daughter).

As told by Olive Boddington: "When you look up at the Seven Sisters, you will see them very clearly: only one is always dull. The dull one is the one the old man is trying to catch but the six sisters are calling to her, telling her to hurry and stay close to them."

This image features on the Nyarluwarri planisphere and is part of the Wajarri Aboriginal Astronomy Planisphere project, an initiative funded by the Australian Government Department of Industry, Science and Resources, CSIRO, ICRAR and the SKAO.

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SKAO