NRF National Research Foundation 25

SCiENCE MaTTERS

Vol:6 | ISSUE:1

Automating ASTRONOMICAL DISCOVERY

Discovering Astronomalies WITH MACHINE LEARNING

REDUCING errors in 21 cm radio survey

Imaging of the SUN WITH MEERKAT

The Great Jupiter - Saturn Conjunction Surprise

The dynamics of GALAXY EVOLUTION

GALLO/GETTY IMAGES

Celebrating 25 Years of Research, Innovation, Impact and Partnerships

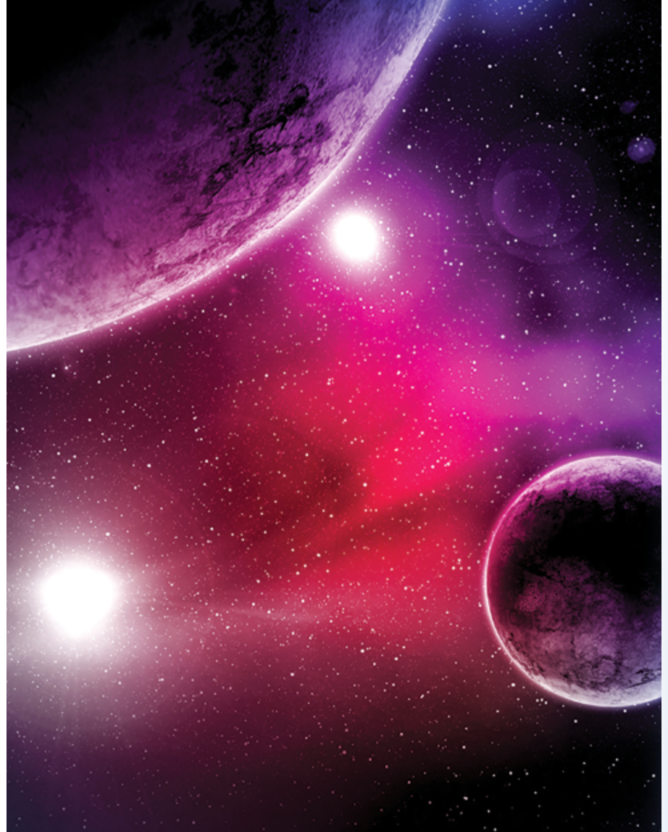
The 1st of April 2024 marked the 25th Anniversary of the National Research Foundation (NRF). Since the commencement of its operations, the NRF has changed the lives of thousands of postgraduates, post-doctoral fellows, and researchers. In the process, it has helped

to equip South Africa with a diverse cohort of knowledge workers who are ready to strengthen our National System of Innovation.

The NRF has also been able to build some amazing research infrastructure, such as the Southern African Large Telescope (SALT), The MeerKAT radio telescope (which is a precursor to the Square Kilometre Array), and the South African Isotope Facility (SAIF) showcase what South African ingenuity can achieve.

In this period, the NRF has launched very successful programmes such as the South African Research Chairs Initiative (SARChI) and the Centres of Excellence (CoE) programme.

These 25 years of investing in research, enabling innovation, and making an impact have been made possible by the support and partnership of all NRF stakeholders!



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SCiENCE MaTTERS

2024 is a significant year for South African and African Astronomy. This year, the African continent will host the International Astronomy Union's General Assembly, the first time the General Assembly has been held on the African continent since the founding of the IAU in 1919.

2024 also marks the 5th Anniversary of the MeerKAT radio telescope. The MeeerKAT which is a precursor to the Square Kilometre Array (SKA) Telescope will be integrated into the mid-frequency component of the SKA. To date, 198 paper have been produced using the MeerKAT. Thanks to the incredible sensitivity of the MeerKAT, it has led to some significant discoveries.

This issue focuses on astronomy, particularly the findings that have been made using the MeerKAT. This is to celebrate the 5th Anniversary of the MeerKAT and to mark the significance of Africa hosting the IAU General Assembly.

We would like to thank all the researchers who generously shared their research and time in helping us produce this issue.

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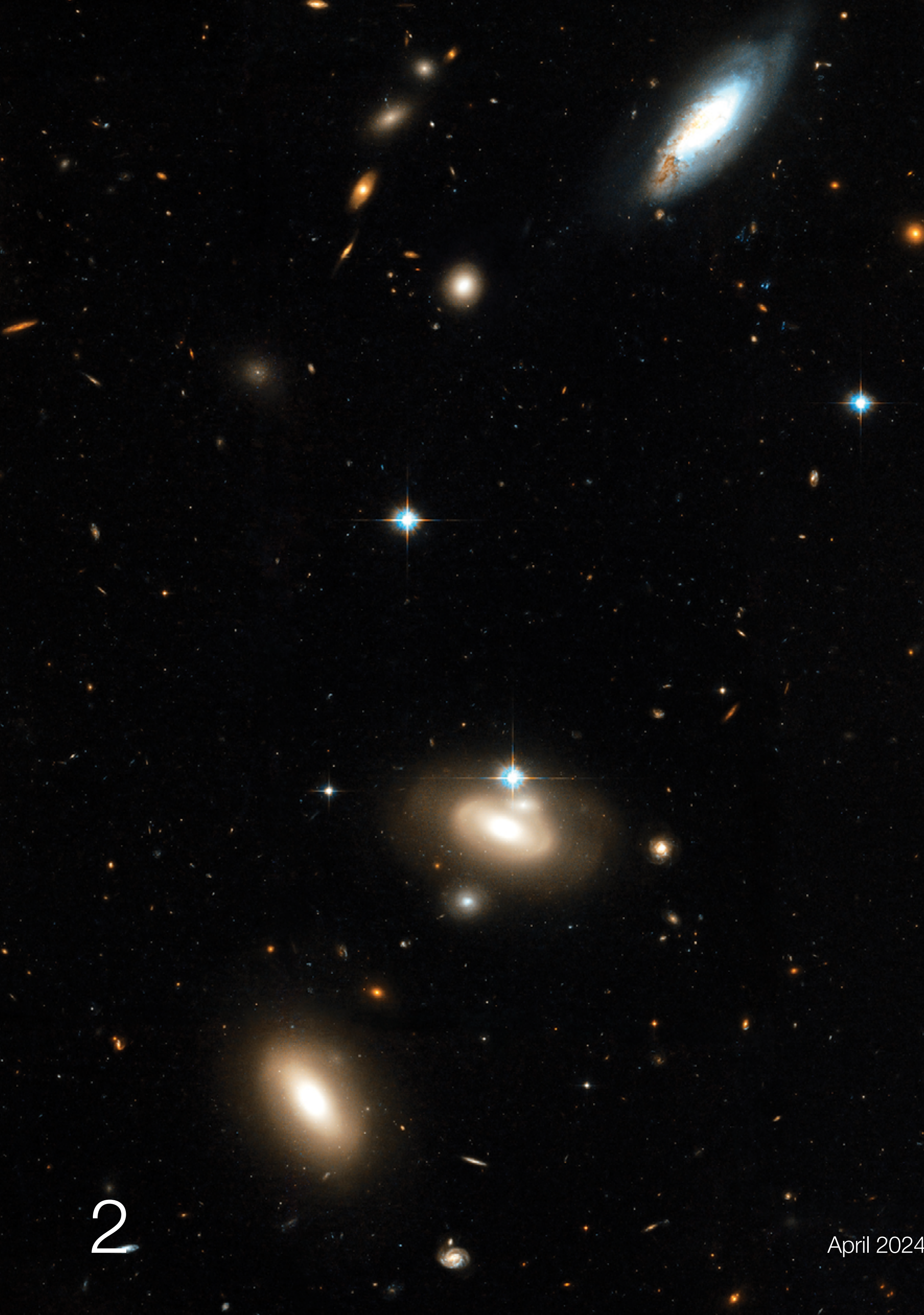
SEARCHING FOR ANOMALIES

Among Four Million Galaxies



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Discover how astronomers leverage machine learning to uncover hidden cosmic anomalies in a sea of four million galaxy images!

Astronomers face challenges in the detection of unusual objects in space due to the huge amount of data generated by modern surveys such as the Sloan Digital Sky Survey (SDSS). The SDSS has catalogued and classified over one billion celestial objects, such as stars, galaxies, and quasars. While other initiatives, such as the Dark Energy Spectroscopic Instrument (DESI) Legacy Surveys, have produced even deeper and higher-quality images of about 1.6 billion sources.

Modern surveys such as the Vera C. Rubin Observatory and the Square Kilometre Array are designed to revolutionise the field even further. These surveys are anticipated to generate petabytes of data and capture unparalleled numbers of astronomical phenomena. For instance, the Vera C. Rubin Observatory is projected to yield a staggering 32 trillion observations of 20 billion galaxies, surpassing the depth of previous large-scale surveys.

A research project funded by the National Research Foundation (NRF) aimed to evaluate the effectiveness and scalability of the anomaly detection framework, called Astronomaly, on a large dataset from the Dark Energy Camera Legacy Survey (DECaLS), comprised of almost four million images. The framework incorporates machine learning, data pre-processing, and visualisation tools. While it has shown promise in the detection of anomalies (the unknown or unclassified astronomical objects), it has not yet been tested extensively on big datasets. The motivation behind choosing to test the method on DECaLS data is that it needs to be thoroughly explored, making it ideal for uncovering new discoveries; the assessment of the Astronomaly's limitations; and evaluation of its performance on larger scale datasets.

The researchers employed a convolutional neural network to extract meaningful representations of galaxy images. The network was trained to capture key features and patterns of anomalous phenomena, which were then fed into the isolation forest algorithm within the Astronomaly framework.

This algorithm utilised a decision tree-based approach to identify anomalies effectively within the dataset. Active learning techniques were also employed to refine the anomaly detection process iteratively. With the incorporation of human expertise, this approach was able to distinguish between scientifically significant anomalies and artefacts, thus improving the accuracy and reliability of the results.

> The Astronomaly framework identified 1 635 anomalies

By testing the Astronomaly framework, the study found that Astronomaly's anomaly detection methods work well on big datasets and can identify interesting anomalies. They identified 1 635 anomalies among the top 2 000 sources in the DECaLS dataset that may have otherwise gone unnoticed, including eight strong gravitational lens candidates; 1 609 galaxy merger candidates; and 18 sources exhibiting highly unusual morphology. These discoveries highlight the power of combining machine learning with human insight to uncover rare and intriguing astronomical phenomena within large-scale astronomical datasets. It also opens up new avenues for exploration and discoveries, such as those expected from the Vera C. Rubin Observatory and the Square Kilometre Array.

Link to the paper :
https://arxiv.org/abs/2309.08660

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Self-Supervised Machine Learning Algorithms Lead to Astronomical Discoveries

Self-supervised machine learning revolutionises astronomy and automates data analysis to uncover hidden cosmic phenomena.

Exciting findings and discoveries have been made by astronomers as they peer into the Universe with super-powerful telescopes such as Meerkat and the SSL. But there are challenges as telescopes become more advanced. Analysis of all the new data can be slow and expensive as it usually requires human capacity to classify it. However, there is a new and more effective method, called unsupervised machine learning, a groundbreaking solution that bypasses the need for human classification and makes data analysis faster and more cost-effective. With this revolutionary approach, scientists can delve deeper into space to uncover even more remarkable discoveries without putting a strain on their budgets.

In unsupervised machine learning, algorithms learn patterns without specific guidance. They achieve this through two main tasks: clustering (grouping similar things together) and anomaly detection (spotting things that are out of the ordinary, such as things that have not been identified before). However, handling complex data, such as detailed galaxy images, can be challenging for some algorithms.

Self-supervised machine learning algorithms streamline astronomical data analysis

Research funded by the NRF has helped adapt a new type of unsupervised machine learning called self-supervised learning (SSL) to the field of astronomy. This innovative algorithm promises to automate space science discoveries, enabling faster exploration of the cosmos. The researchers utilised the SSL algorithm to streamline data analysis in their study. The accuracy of the simplified data was then validated using a comprehensive collection of detailed galaxy images from DECaLS, organised by scientists collaborating on the Galaxy Zoo project.

The research findings revealed that the SSL algorithm has the capability to group galaxies automatically based on their similar visual attributes, including classic spirals, as well as more subtle features such as ring formations. Moreover, the study discovered that this unsupervised machine-learning technique can assist in detecting rare morphologies, such as potential merger candidates. Additionally, the research highlighted that this methodology can be effectively employed to analyse radio data, thereby making it widely applicable without the need for significant changes to the setup.

The ISSL algorithms have become an essential tool in various fields due to their versatility and adaptability. From language processing models such as BERT (Google), LLaMa (meta), and ChatGPT (OpenAI) to robotics, bioinformatics, finance, and medical imaging, these algorithms have proven to be powerful techniques in numerous applications. As technology continues to advance, we can expect to see even more innovative uses of SSL algorithms. SM

https://arxiv.org/abs/2311.14157

Exploring Space with **Radio Telescopes**

Scientists uncover the challenges and solutions in accurately mapping the universe's vast neutral hydrogen landscape.

Neutral hydrogen (HI) makes up about 75% of the Universe's composition, along with other elements such as helium, oxygen, carbon, and nitrogen. This hydrogen is composed of tiny particles called protons and electrons. Every 11 million years, these particles become energised and alter their direction. When the particles alter their direction, they release a photon at a specific wavelength of about 21 centimetres. Instruments such as the Meerkat telescope are capable of detecting these signals.

Scientists study these signals to create maps showing how the HI is distributed in space; the study is called the HI intensity mapping. These maps help them understand how stars and galaxies are spread out across the sky. However, when using telescopes such as Meerkat to collect this data, they encounter external and internal challenges. One major internal challenge is the 'telescope beam', which refers to how the telescope sees the Universe during observations, which can negatively impact the collected data.

To understand how the radio telescope's beams influence the collected data, research funded by the NRF looked into how the Meerkat telescope's observation methods affect their HI intensity mapping studies. They focused on something called 'beam sidelobes', a technical part of the telescope that can interfere with what the telescope sees, especially when there are bright objects in space during the observation. Understanding this is important as it helps to ensure that the pictures the telescope takes are accurate.

During the investigation, the researchers relied on computer simulations; they made computer versions of what the telescope sees using computer algorithms and tested different data analysis methods. They also studied how the telescope responds to different frequencies and found ways to handle these differences effectively.

Their research uncovered that the way in which the telescope observes can affect its ability to detect certain phenomena in space. However, they were able to enhance the telescope's performance and attain improved results by using more accurate models of its behaviour, even when bright objects were present in space. Additionally, they discovered that the telescope behaves differently depending on the frequency of the signal, which can negatively impact data collection for studies on neutral hydrogen.

The researchers found that radio telescopes such as Meerkat and the upcoming SKAO are incredibly useful for HI intensity mapping studies. This means that there is an opportunity to learn a lot more about our Universe using these instruments. However, they also emphasised the importance of addressing any challenges that may arise, especially when examining small areas of space. They also suggested improving data collection methods and signal filtering techniques for future research. Additionally, they plan to apply their findings to actual observations from Meerkat, which will help verify their conclusions. SM

https://doi.org/10.1093/mnras/stab1688

MeerKAT@5 Conference Celebrates Five Years of Scientific and Engineering Achievements

The MeerKAT@5 conference took place from 20 to 23 February 2024 in the beautiful town of Stellenbosch, in the heart of the Cape Winelands; Attendees were invited to celebrate the wide-ranging successes of this multifaceted African project.

The event highlights and presentations covered the following topics:

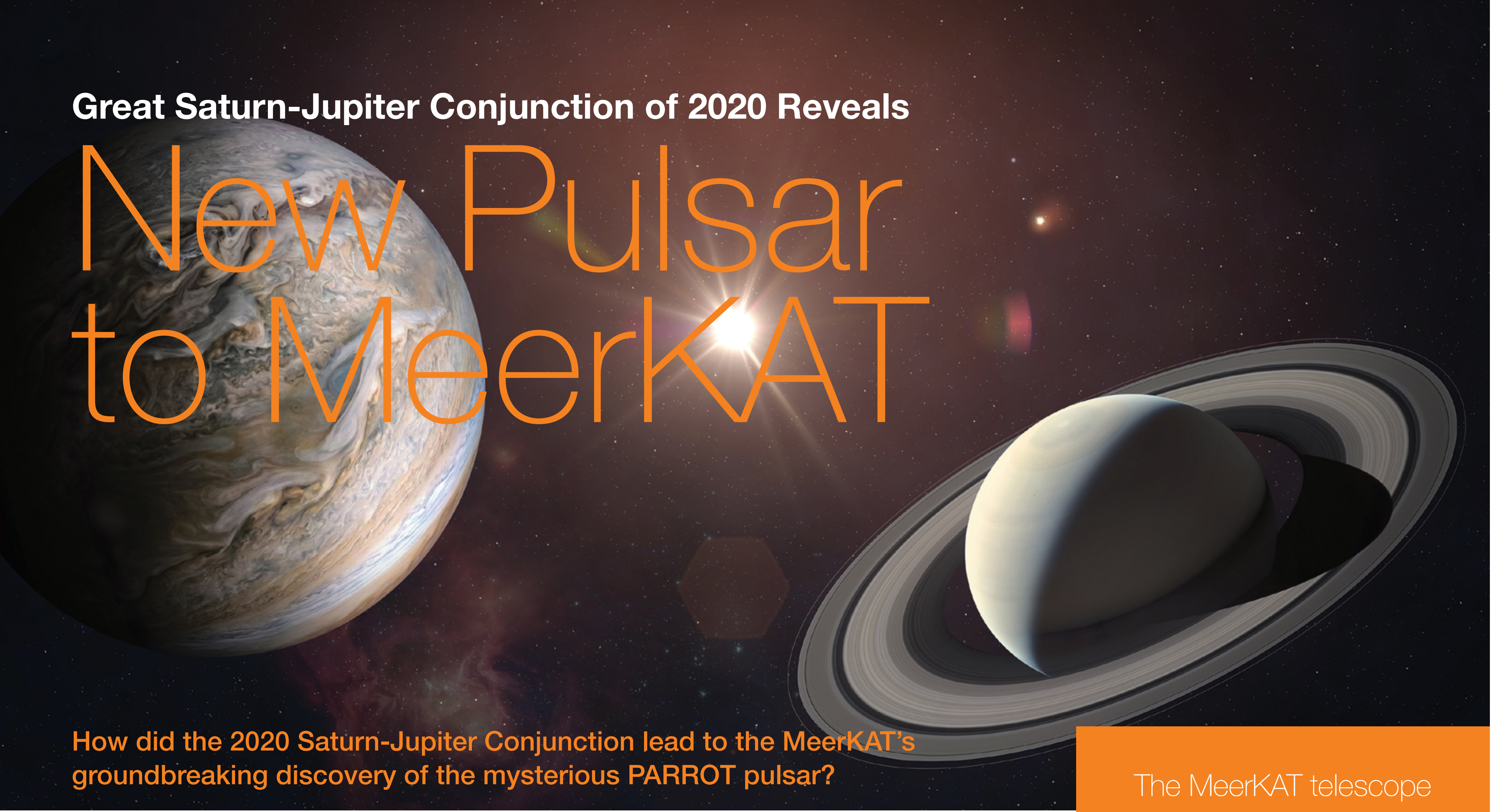
- High-impact MeerKAT science results
- The innovative engineering required to deliver the instrument
- The history of the project and its broader impact
- The future of radio astronomy in the African continent

To view the papers and presentations delivered at the conference follow this link

https://zenodo.org/communities/meerkat5/records

Great Saturn-Jupiter Conjunction of 2020 Reveals

New Pulsar to MeerKAT



How did the 2020 Saturn-Jupiter Conjunction lead to the MeerKAT's groundbreaking discovery of the mysterious PARROT pulsar?

The discovery of the PARROT pulsar by researchers using the MeerKAT radio telescope was a significant breakthrough in astronomy. This revelation, published in the Monthly Notices of the Royal Astronomical Society journal, showcased the power of MeerKAT and hinted at more exciting discoveries to come.

Throughout history, astronomy has been filled with unexpected finds. Some astronomical finds are serendipitous, revealing hidden treasures previously unseen. South Africa is fortunate to host the MeerKAT, an instrument widely considered the best radio telescope in the world, which provides opportunities for groundbreaking discoveries.

This exciting pulsar was discovered during the processing of the data observed during the Great Saturn-Jupiter Conjunction of 2020. This rare event brought the two gas giants closer together than they have ever been in centuries. While everyone was excited to witness the event, no one expected it to lead to any new discoveries until MeerKAT came into play.

Radio telescopes such as MeerKAT are typically used to observe distant objects that change very slowly, if at all. However, planets are constantly in motion. To capture accurately any subtle changes or movements, MeerKAT had to create a 'movie' of the scene. This was made possible by the dedicated efforts of the Rhodes Centre for Radio Astronomy

GALLO/GETTY IMAGES

> The MeerKAT telescope discovered the unique PARROT pulsar

Techniques & Technologies (RATT) team, winners of the NRF Science Team Award for 2023, and the Radio Astronomy Research Group (RARG) at the South African Radio Astronomy Observatory (NRF-SARAO), who produced incredible visuals showcasing the deep MeerKAT scenes.

The movie revealed fascinating features, such as Jupiter's radiation belts and glimpses of intriguing radio galaxies with supermassive black holes at their centres, emitting plasma jets that give them a distinctive double-lobed appearance. However, the most surprising moment occurred when scientists noticed something strange in the movie: a sudden flash of radio signal near Saturn which lasted about 45 minutes before disappearing. This discovery was fortunate, as it would have been challenging to detect in a regular image.

Such rapid space events are rare and often indicate something exciting is occurring. Following this surprising discovery, scientists directed the MeerKAT telescope to reobserve the same spot in the sky on several occassions over the next few months, and found that the flashes persisted. Eventually, MeerKAT detected bursts of pulsations coinciding with the flashing. This revelation confirmed that they were witnessing a pulsar, a dense star remnant formed after a massive star explodes. Pulsars rotate rapidly and emit beams of radio waves. When one of these beams aligns with Earth, telescopes capture brief pulses of radio waves each time the pulsar rotates – in this case, every 1.6 seconds. The newly discovered pulsar was named PARROT, an abbreviation for Pulsar with Anomalous Refraction Recurring on Odd Timescales.

The PARROT pulsar is remarkable due to its signal which undergoes significant changes. While many pulsars have been observed previously, the PARROT's signal can intensify dramatically, sometimes increasing tenfold or more within minutes. In some instances, its signal increases abruptly to almost a hundred times its usual strength, which is quite surprising. This unusual behaviour is believed to be influenced by charged particles in space called plasma, which can scatter radio signals. However, the PARROT's signal boost suggests that something distinct may occur with large bubble-like structures within the plasma. Understanding this mystery is an exciting challenge to be observed in the future.

Link to the paper :
https://doi.org/10.1093/mnras/stae303
The movie : jove-27scan-pol.png (2090×2000) (radiopadre.net), jove-27scan-pol.png (2090×2000) (radiopadre.net)

SAVE THE DATE

06 – 15 August 2024,
Cape Town, South Africa

Join the historic IAU General Assembly 2024 in Cape Town.

Exciting news! Astronomers from all over the world will gather in South Africa for a special meeting; the first of its kind to take place on the African continent. The meeting is scheduled to take place from 06 to 15 August, 2024 in Cape Town, South Africa and will cater not only to astronomers but also accommodate everyone, and you will not want to miss it.

The International Astronomical Union (IAU) General Assembly (GA) has been around since 1919. Its main goal is to support and protect astronomy worldwide through cooperation in areas of research, education, and progress. The General Assembly takes place every three years and brings together astronomers from all over the world. It is the biggest international event in astronomy, where important decisions are made and collaborations are formed. This particular GA is historic in that it provides a platform to change the narrative about how people see Africa globally by highlighting its leadership in areas such as astronomy. It challenges stereotypes about Africa's abilities, especially in science.

At the centre of this event, the organisers emphasise three important principles: accessibility, impact, and environmental sustainability. This means that everyone everywhere can join in. For the first time, the assembly will be completely open-access, with live talks and discussions available to anyone with an internet connection. The aim is to make astronomy knowledge available to everyone; to inspire a new generation of enthusiasts, and to ensure global engagement.

The influence of the IAU General Assembly goes beyond academia. There are planned special events with the aim of creating a lasting impact. These activities include tours of astronomy facilities throughout Africa; involvement with local schools and communities during National Science Week; taking part in the IAU GA2024 AstroFest; and flagship #AfricaLookUp, a project that blends astronomy with art to celebrate Africa's rich cultural heritage.

This event is more than just a gathering for astronomers. If you don't want to miss out, check their website for registration and access details: *https://astronomy2024.org/*.

This is a big opportunity for Africa to shine in the world of science. As people come together in Cape Town, they can inspire, teach, showcase scientific discoveries, and change how people see things. This is not just about looking at stars; it's about changing how we think about our universe. SM

GALLO/GETTY IMAGES

The Dynamics of Galaxy Evolution:

Insights from Group Environments

Discover how group environments impact the abrupt halt of star formation in galaxies and unravel the enigma of ‘quenching.’

The Universe is home to many galaxies, each with its own unique family, morphology, and shape. These galaxies can be classified broadly into three main categories: spiral, elliptical, and irregular. Interestingly, the colour of these galaxies is either blue or red, and this colour conveys important information about the galaxy’s age and the rate at which it forms new stars.

The blue galaxies are those that actively form new stars from the Universe’s cold gas, whereas red galaxies have either slowed down in production or completely stopped the production of new stars. Blue galaxies are often called young galaxies since they continue to form stars until they start to slow down and eventually become red galaxies. However, there are instances where a blue galaxy that is actively forming stars suddenly stops the production of new stars within a billion years without any specific event stopping the star formation process. This sudden halt is known as ‘quenching’ and is different from the process of ‘ageing’ where the galaxy slowly stops the formation of new stars over time. The phenomenon of quenching is not yet fully understood and continues to be a topic of research in the field of astrophysics.

Since many galaxies in the Universe are part of groups, scientists believe that their environment affects the way star formation stops in a galaxy. For example, are the quenching galaxies isolated with no galaxy neighbours, or are they part of a group or cluster of galaxies close together? Research funded by the NRF studied 10 galaxies in a nearby galaxy group known as Fornax A to learn more about how they change over time. Using the South African MeerKAT radio telescope, scientists were able to get a closer look at the cold gas in these galaxies, which is where new stars can originate.

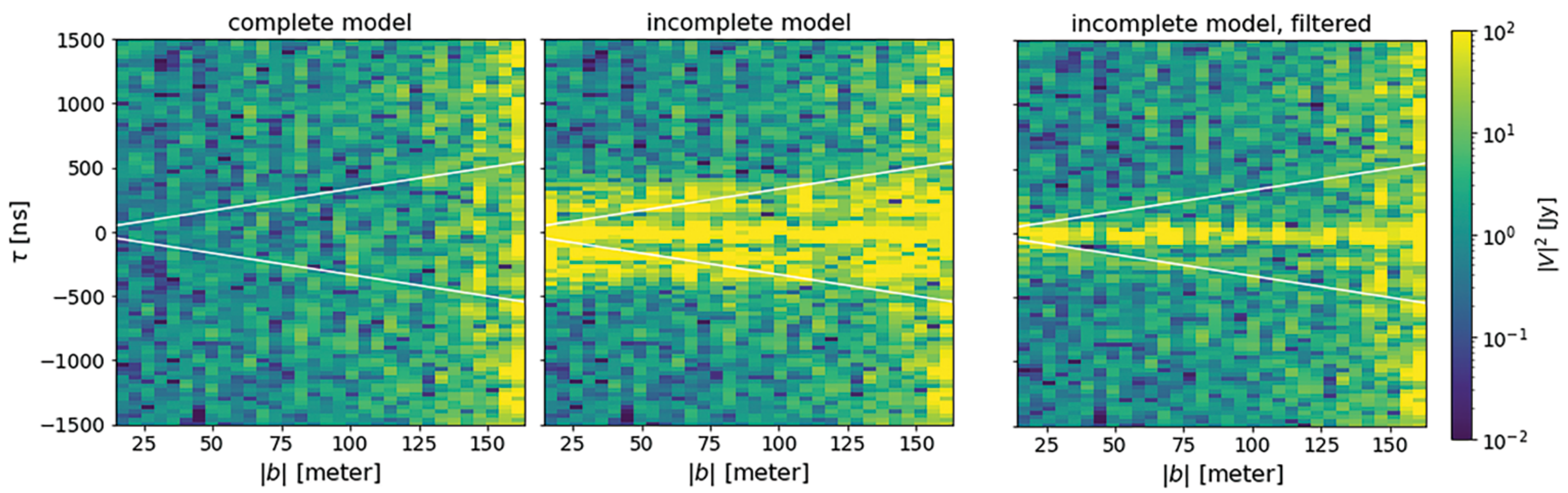
During the investigation, the researchers also used the Southern African Large Telescope (SALT), the largest single optical telescope in the Southern Hemisphere, to measure the ages of the stars in the galaxies, which helps figure out when star formation in these galaxies might have slowed down or stopped completely.

The research revealed that, despite being in the same group environment, some galaxies have experienced different events over the past billion years. Most galaxies have evolved to follow a regular pattern, but some have had unique histories that lead to a sudden decline in star formation, also known as quenching. Additionally, the study indicates that star formation initially stops in the outer regions of galaxies, while new stars continue to form in the central part of galaxies.

> Group environments don’t significantly influence the quenching of star formation in galaxies.

Overall, the research suggests that the galaxy group environment does not effectively influence the quenching of star formation in galaxies. The researchers have broadened their focus to examine the histories of galaxies in denser cluster environments. They use observations from the SALT telescope to see if this approach is more effective in halting star formation in galaxies. SM

https://academic.oup.com/mnras/article/527/3/7158/7452896



New Filtering Technique to Reduce Errors in 21 cm RADIO SURVEYS

A breakthrough in radio astronomy promises clearer insights into the Epoch of Reionisation.

A problem encountered regularly by astronomers performing 21 cm cosmological radio surveys is foreground contamination. Such contamination can come from a variety of sources such as from the Galactic synchrotron (cosmic ray electrons accelerated by the Galactic magnetic field); free–free emission (free electrons scattering off ions largely within our galaxy), and point sources (extragalactic objects emitting strong radio signals, e.g. active galactic nuclei. This can make it difficult to separate foreground "noise" from the 21 cm signal.

A team of seven researchers from the South African Radio Astronomy Observatory (NRF-SARAO) as well as from the USA, UK, and Italy, have developed a technique designed to suppress the calibration bias through the utilisation of "temporal filtering" of radio interferometric visibilities. The team demonstrated the technique using simulations of the Hydrogen Epoch of Reionization Array experiment, located in the MeerKAT National Park outside of Carnarvon in the Karoo region of the Northern Cape. HERA is a low-frequency radio interferometric array designed to probe the Epoch of Reionization (EoR) and forms part of the Square Kilometre Array.

The 21 cm emission from the hyperfine transition of neutral hydrogen is considered by astronomers to be one of the best observational probes of the EoR, a period of time from approximately 400 million to 1 billion years after the Big Bang during which radiation from already formed galaxies and quasars began to re-ionise the Universe's intergalactic medium, which, up until that time, was neutral. EoR experiments all face the problem of bright foreground interference from the galaxy and extragalactic sources, often up to five orders of magnitude brighter than the 21 cm emission.

In order to deal with this problem, interferometric data must be calibrated using, among other things, sky models, usually compiled from source catalogues. Unfortunately, these source catalogues do not fully characterise sky emissions due to limited sensitivity and angular resolution. The sky models also tend to exclude diffuse galactic synchrotron emission and do not fully account for low-frequency sky brightness distribution. This leads to errors in calibration which impacts on the "cleanness" of the 21 cm cosmological signal.

There have been other techniques to reduce reliance on sky models such as redundant calibration but these techniques are themselves inherently problematic in that they still require the use of a sky model.

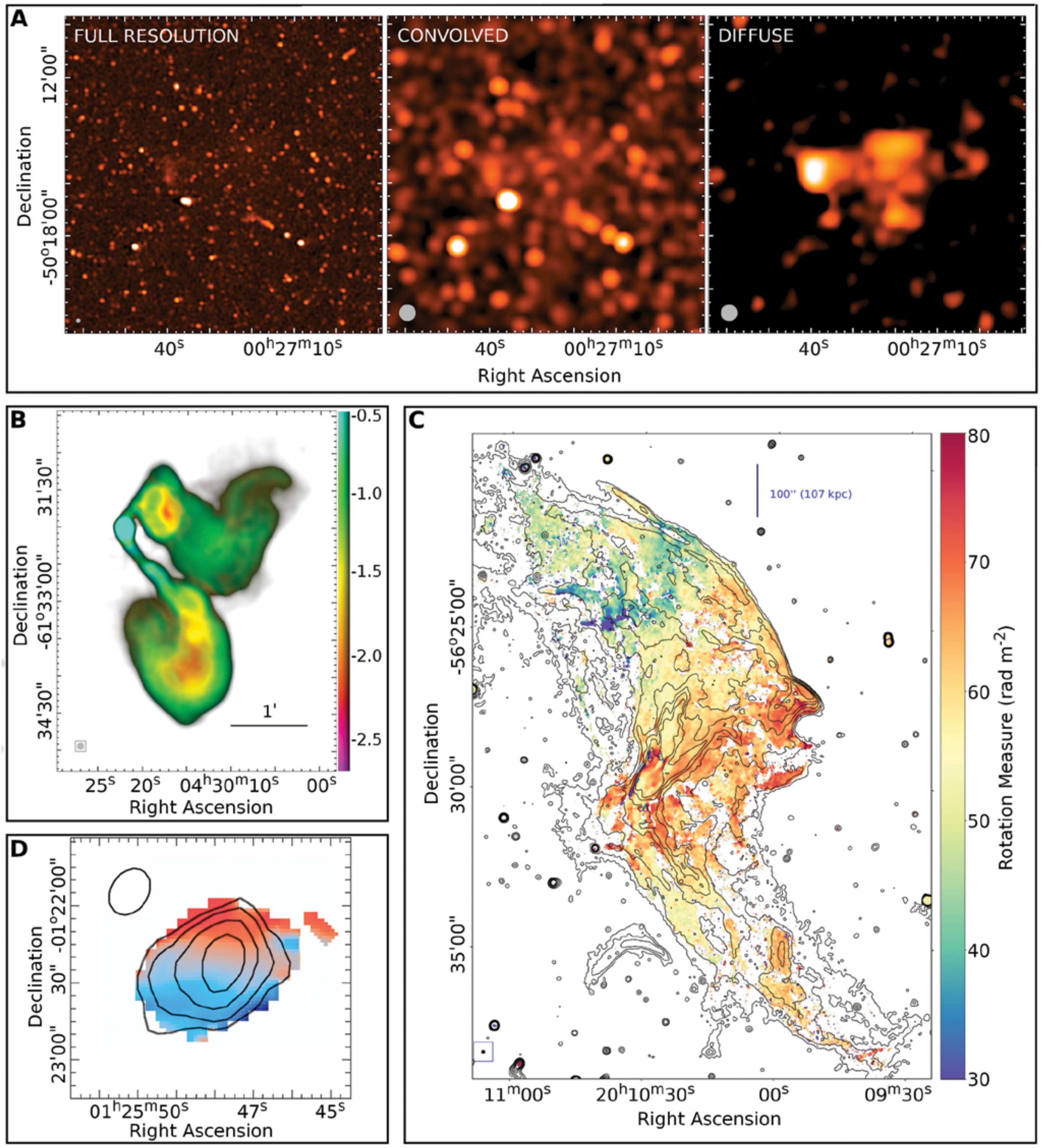
The researchers chose to use HERA due to its sensitivity to large angular structures such as the galactic synchrotron emission. There aim was to improve HERA calibration by filtering diffuse emission in the data prior to running the calibration. This would help to mitigate its impact on the recovered antenna gain solutions. The team looked at two types of filters – a simple high-pass filter (or baseline-independent filter) and a baseline-dependent filter. The former suppresses only foreground emissions centred at zero fringe rate mode while the latter suppresses all emissions that is inconsistent with point sources in the field of view of the primary beam.

> Temporal filtering reduces foreground contamination

Realistic HERA observations were simulated where the researchers included point sources, extended sources, and a diffuse galactic component in the sky model. The observations were corrupted with mock gains and then pushed through HERA's redundant and absolute calibration pipelines. The researchers observed calibration bias when no filters were used in the form of spurious frequency structure. After applying the filters before calibration, the biases were substantially reduced. The foreground leakage was reduced to the simulated noise floor in the data and, when applied to noiseless simulations, the technique yielded gain solutions accurate at 1 part in 105 in dynamic range – roughly the estimated calibration requirement for detecting EoR with HERA.

The researchers believe that their technique can be applied in a variety of areas such as the Canadian Hydrogen Intensity Mapping (CHIME) but not instruments such as the Square Kilometre Array (SKA) or Low-Frequency Array (LOFAR). SM

The paper can be accessed: *https://doi.org/10.1093/mnras/stad1046*.



The MeerKAT Galaxy Cluster LEGACY SURVEY

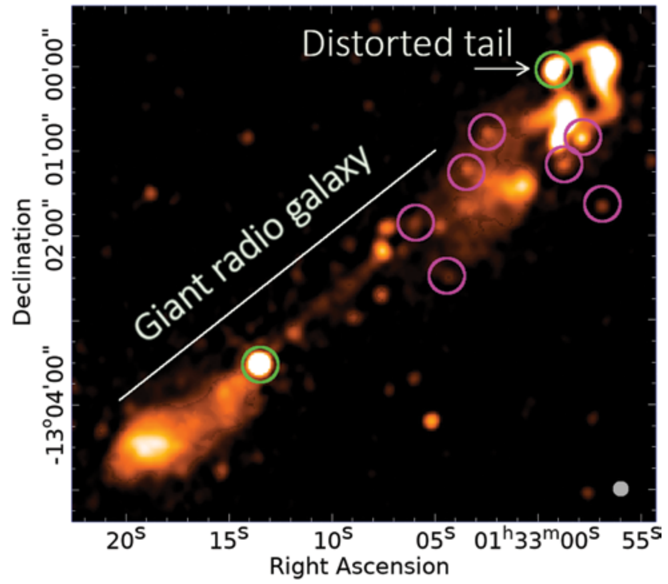
Intriguing galaxy cluster mysteries redefine our understanding of the Universe

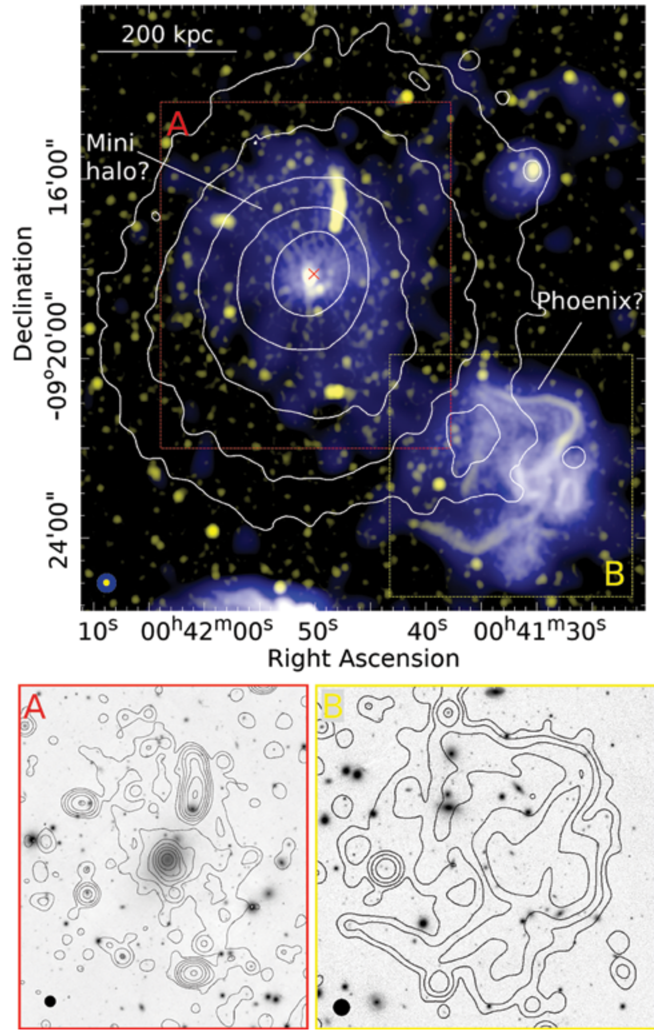
An international team of researchers from universities and science institutes has completed a survey of more than one hundred galaxy clusters observed by the MeerKAT radio telescope, dubbed the MeerKAT Galaxy Cluster Legacy Survey (MGCLS). The survey, derived from over 1 000 hours of telescope time, provides the deepest radio images of these cluster regions yet, revealing hundreds of thousands of sources, many of which exhibit interesting morphologies.

Galaxy clusters are the largest gravitationally bound structures in the Universe and provide data-rich observations for researchers. They are characterised by dark matter which represents the bulk of their composition. Around 13% of their mass is ionised plasma of the intracluster medium, or ICM (the superheated plasma found throughout galaxy clusters), and only about 2% from the cold gas and stars of their constituent galaxies. These clusters have also revealed steep-spectrum diffuse radio emissions which astronomers can use to study the distributed populations of cosmic ray particles and magnetic fields in the ICM. These structures are linked to cluster mergers, which enables researchers to study shock physics, merger-related turbulence, and other particle re-acceleration phenomena.

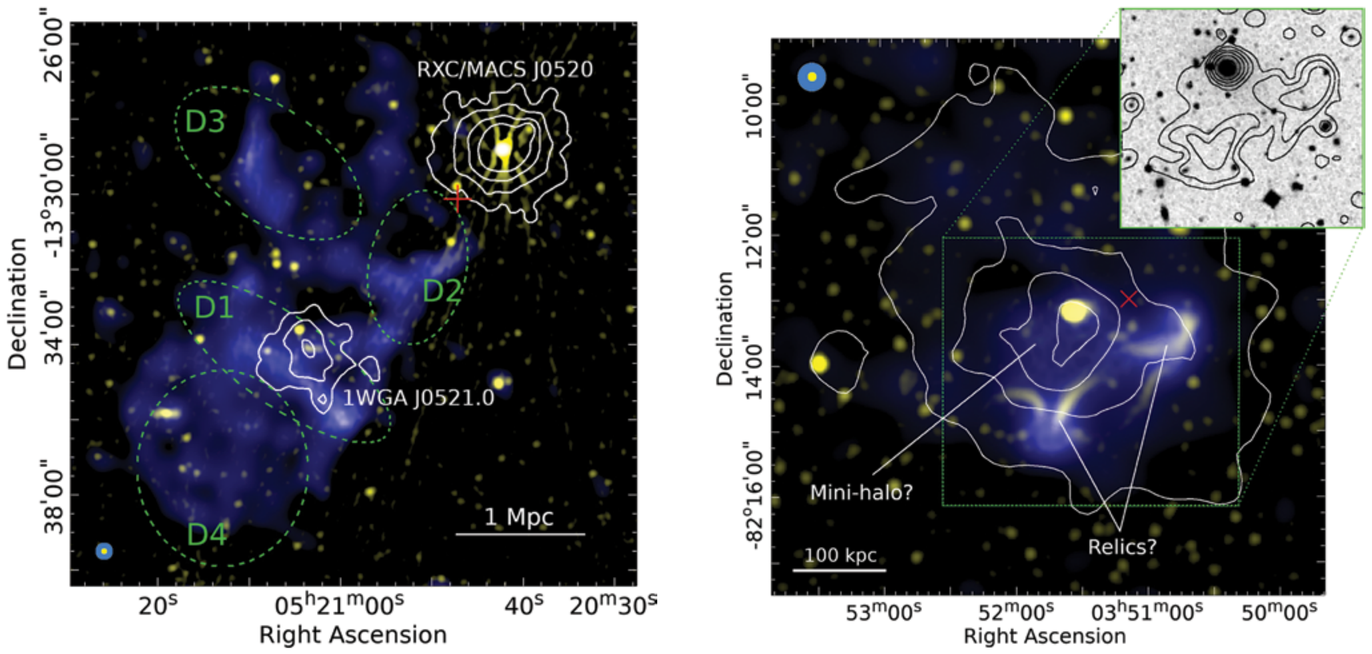
The MeerKAT radio telescope, located outside of the town of Carnarvon in the Karoo region of the Northern Cape, is a collection of 64 radio antennas, each measuring 13.5 m in diameter,

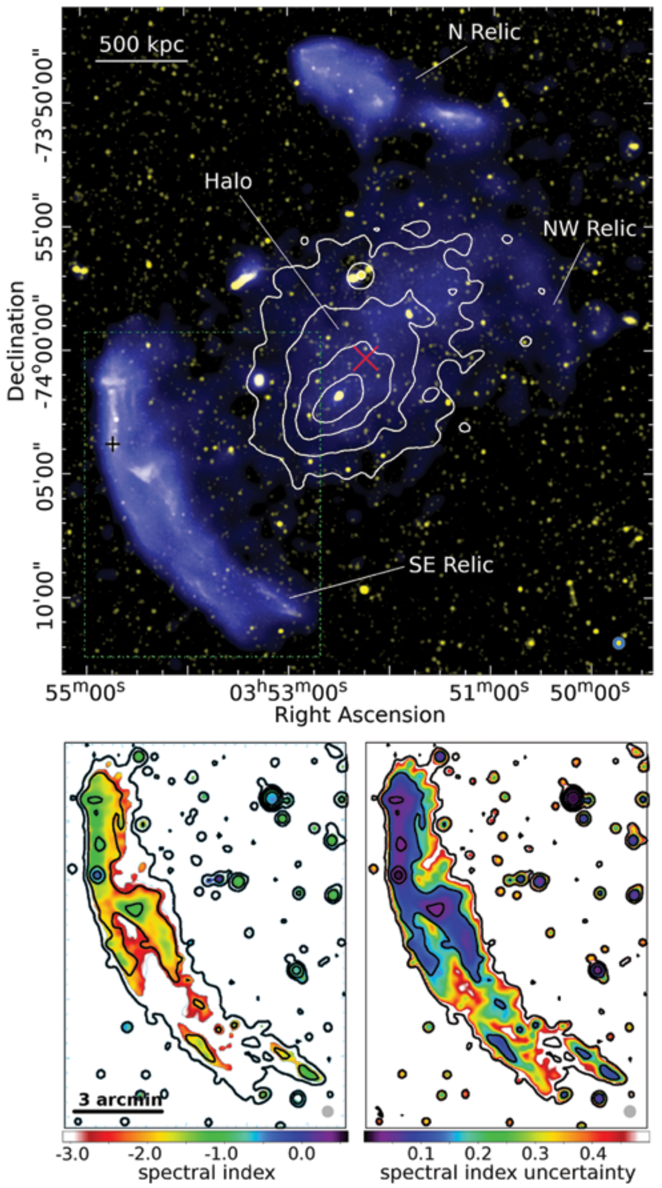
Radio images reveal novel structures





spanning 8 kms and with a densely packed core of 1 km. It will form part of the Square Kilometre Array (SKA) and its sensitivity and array configuration make it a powerful instrument capable of providing >





wide area surveys with high sensitivity over a wide range of angular scales, ideal for galaxy cluster studies.

The MGCLS team analysed several aspects of the data, making some significant findings including:

- The lowest luminosity radio relic candidate detected to date. A radio relic is a diffuse, elongated radio source of synchrotron origin, which forms in single or double symmetric arcs on the edges of galaxy clusters.
- Large-scale diffuse structures that fall outside of conventional classifications of mini-halos, halos, or relics.
- Radio galaxies with structures that cannot be explained using current astronomical models.
- No positional trend in the rate of star formation in cluster galaxies out to previously unexplored cluster radii (in the radio regime).

The survey images and a compact source catalogue consisting of more than 626 000 galaxies have been released to the community. The team believes that their results represent only a small fraction of what can be achieved with the legacy dataset and that the astronomy community is likely to make many more significant contributions. SM

https://doi.org/10.48550/arXiv.2111.05673.

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Join Us on the Science Matters Podcast!

As a NRF-funded researcher, are you ready to share your research insights and contribute to captivating conversations that ignite curiosity worldwide? If so, we're thrilled to invite you to be part of our podcast! Regardless of field or level of expertise, we welcome you to join our guest list. Simply email your research article(s) to sciencematters@nrf.ac.za or M.Sibiya@nrf.ac.za, and let's discuss your work in our studio. We're excited to collaborate with you and delve into the fascinating realms of science together.
We look forward to seeing you on our podcast!

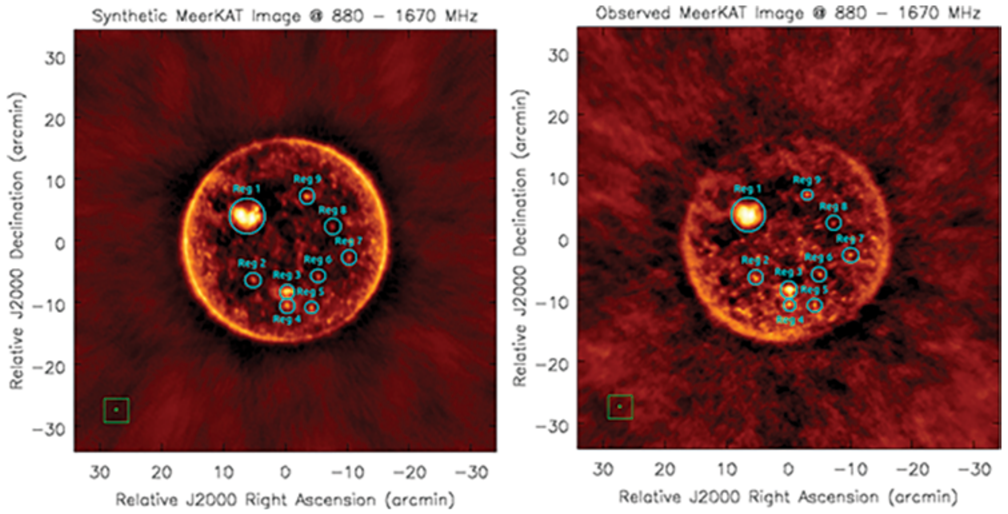

Figure caption : This figure demonstrates the fidelity of solar radio image produced using MeerKAT solar observation. The left panel shows a simulated image of the Sun, which we expect to see with MeerKAT. The right panel shows the true MeerKAT image obtained from MeerKAT observations. True image exceptionally matches with the simulated image. Even small and faint features are detected in the true image, some of them are marked by blue circles in both these images.

Spectroscopic Imaging of the **Sun with MeerKAT**

Solar radio emissions play an important role in understanding the solar corona and its associated phenomena. Unfortunately, it is very challenging to image coronal emissions, particularly at radio wavelengths. A team of researchers from India, South Africa, the USA, the UK, and Nigeria have used South Africa's MeerKAT radio telescope to observe and publish high fidelity spectroscopic images of the Sun, the first time the instrument has been used for such observations.

According to the team, there has been a range of new instruments built in recent years that can enhance the study of the Sun, and MeerKAT is one of those instruments. Located in the Northern Cape's Karoo region near Carnarvon, MeerKAT is a precursor to the Square Kilometre Array (SKA) and consists of 64 radio dishes, each with a diameter of 13.5 m, distributed across an 8 km radius. It offers a very high dynamic range and surface brightness sensitivity due to an excellent spectroscopic snapshot sampling in the Fourier plane.

Solar observations using radio telescopes such as MeerKAT can be challenging. In order for the instrument to be used effectively for solar observations, these challenges need to be addressed. First and foremost, MeerKAT was designed for observing faint astronomical sources. However, the Sun has flux density a few orders of magnitude higher than other astronomical sources in our sky. So the solar signal needs to be attenuated (reduced in amplitude) considerably. This becomes a problem because the astronomical sources of calibration for the MeerKAT are many times weaker than the Sun. To solve this problem, the team observed the Sun by pointing the dishes of MeerKAT about 2°.5 away, keeping the Sun in the sidelobes of the primary beam in order to attenuate the emissions. In this manner, the team was able to obtain observe the Sun with MeerKAT and make flux density calibrated solar images.

The team's work represents the first detailed spectroscopic imaging study of the Sun using MeerKAT, which, while it has not yet been commissioned for solar observation, helps to clear the way for future work. Researchers compared a true MeerKAT solar image with an expected image produced by simulation and found exceptional similarities. One such example is shown in the figure below, which demonstrates MeerKAT's ability to answer several open questions in solar physics related to solar flares, coronal mass ejections, coronal heating, and solar wind. The researchers believe their work will increase the understanding of radio emissions from our Sun. SM

https://doi.org/10.48550/arXiv.2307.01895


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