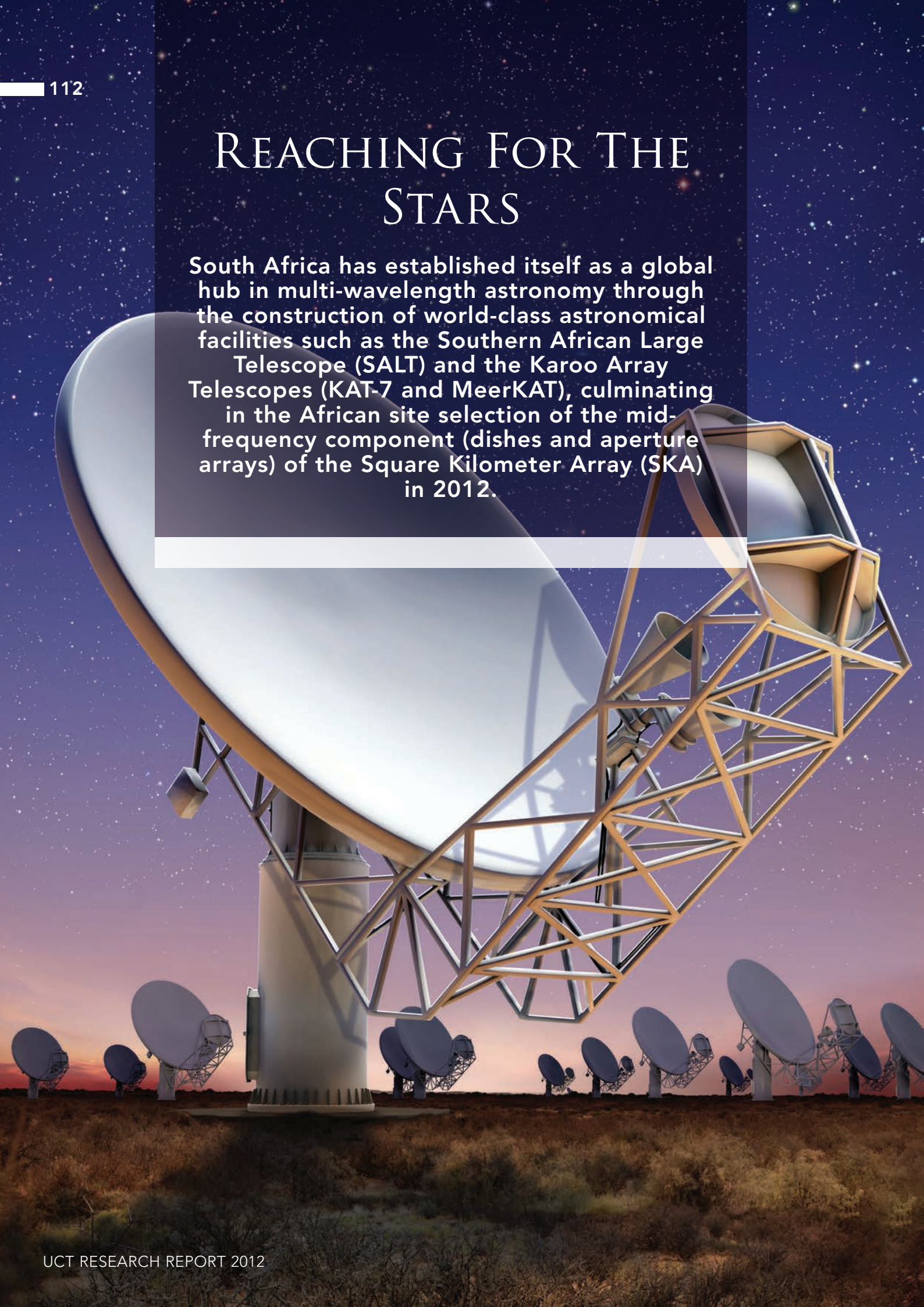
Reaching For The Stars

South Africa has established itself as a global hub in multi-wavelength astronomy through the construction of world-class astronomical facilities such as the Southern African Large Telescope (SALT) and the Karoo Array Telescopes (KAT-7 and MeerKAT), culminating in the African site selection of the mid-frequency component (dishes and aperture arrays) of the Square Kilometer Array (SKA) in 2012.



The site decision by the international SKA consortium was welcomed by UCT as a red-letter day in the development of science in South Africa. Astronomers at UCT and across the country celebrated the outcome of the site bid and congratulated Dr Bernie Fanaroff, head of the SKA South Africa project, on this achievement.

This is one of the biggest scientific research ventures ever undertaken and it confirms that developing nations can also be part of solving the big questions of our day. It will bring scientists from all over the world to South Africa (and to UCT in particular) and thus greatly enhance not only South Africa's but also UCT's international research collaboration.

Work on the South African SKA precursor array entered a new and exciting phase in 2012 with the commissioning of the seven-dish radio interferometer KAT-7. Across the various science teams involved with the MeerKAT SKA precursor array, the staff and postdoctoral research fellows of UCT's Astronomy Department in particular are actively participating in the commissioning phase of KAT-7.

The department is also leading the early science enabled by the KAT-7 array, exploring the unique capabilities that a combination of the world's largest optical telescope – the 10 metre Southern African Large Telescope (SALT) – and the SKA precursor offer in studying the universe.

Observations taken in 2012 with KAT-7 of the accreting neutron star binary Circinus X-1, and the nearby galaxy NGC3109, show the excellent potential of KAT-7 for long-term monitoring of actively varying binary stars in the Milky Way (Circinus X-1) and studying the extended emission from nearby galaxies respectively. Both observations have been accepted for publication in prestigious astronomy journals.

In 2012, the Department of Astronomy also welcomed Professor Thomas Jarrett from the California Institute of Technology, as the incoming DST/NRF SARChI Chair in Astrophysics and Space Science. Professor Jarrett works on the study of extragalactic large-scale structures, the Zone of Avoidance, interacting galaxies, star formation processes and galaxy evolution.

The research of Professor Jarrett dovetails with that of the DST/NRF SKA Chair in Extragalactic Multi-wavelength Astronomy, a position held by Professor Claude Carignan, who specialises in the study of stellar and gas motions in galaxies through radio and optical observations of nearby galaxies.

The number of postgraduate students in the Department of Astronomy reached new heights in 2012: 15 PhD and 19 MSc students were registered for their postgraduate research degrees in astronomy. These postgraduate students are predominantly from South Africa (22), with additional representation from amongst the SKA African partner countries – Madagascar (four), Mauritius (two) – and a range of other countries, including Uganda, Egypt, Ethiopia, France, India and the USA.

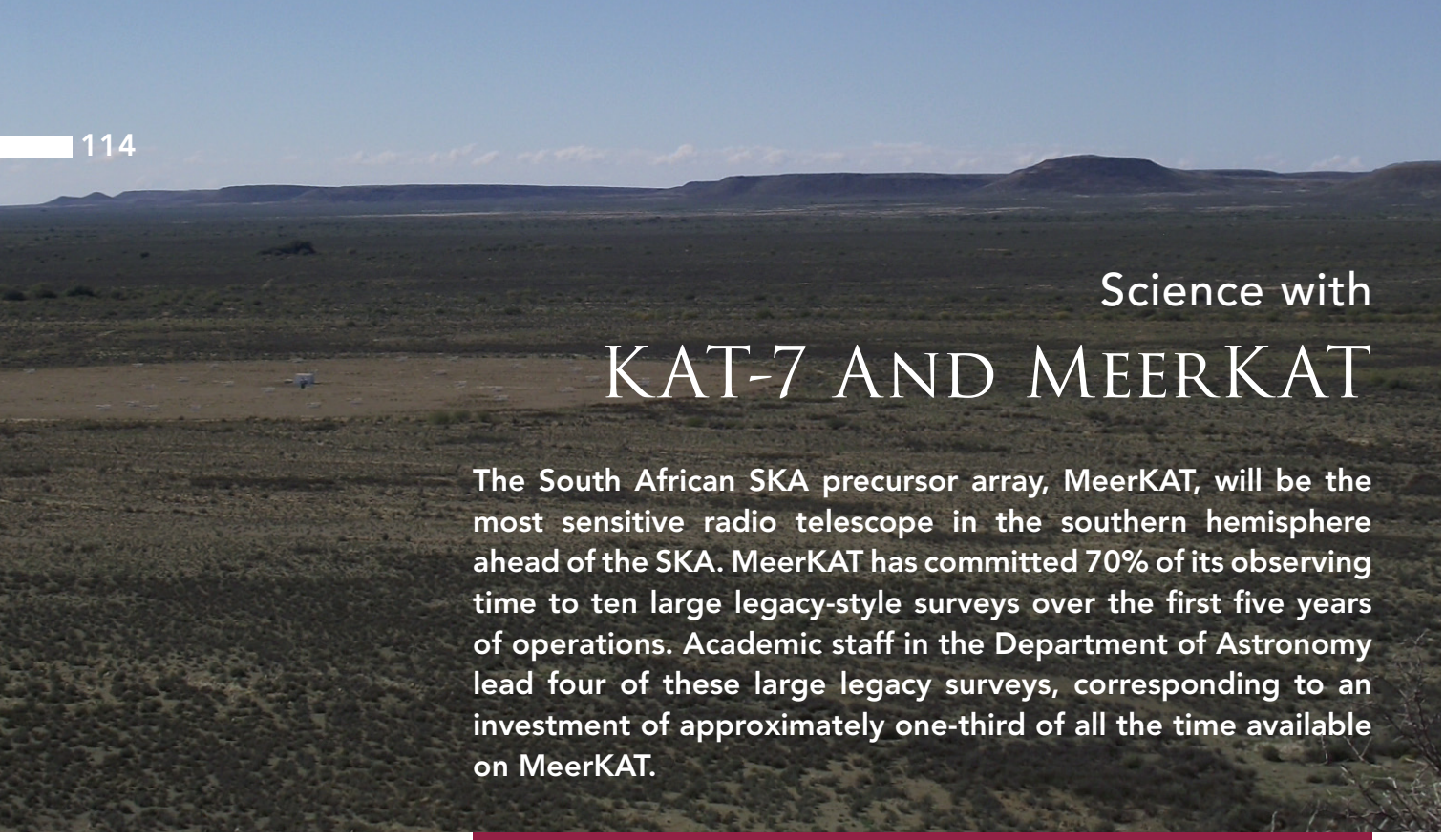
Dr Bernie Fanaroff

Through support from the DST/NRF South African Research Chairs Initiative, the National Astrophysics and Space Science Programme (NASSP), the Youth in Science and Engineering capacity development programme of the SKA South Africa project, UCT's Astronomy Department – often jointly with the South African Astronomical Observatory – is preparing the next generation of African astronomers to take on leading roles in the scientific exploration of the universe with SALT and the SKA.

The highest number of postgraduate research students in astronomy at UCT to date graduated in 2012. Of the eight students who graduated, four will continue their careers in astrophysics abroad: one student was selected as a Rhodes Scholar to pursue a DPhil at the University of Oxford, and three have gone to the Netherlands (to embark on PhD studies at the universities of Groningen and Nijmegen) and will be jointly supervised by UCT faculty.

On average, approximately 80% of UCT's astronomy graduates continue to postgraduate studies and about one-third go overseas after completing their UCT degree (MSc or PhD) to continue their academic careers. It is particularly heartening to see that many of them return to South Africa to take up postdoctoral research fellowships or even permanent academic positions.

Apart from the essential international experience, these young researchers bring back new research collaborations and networks to the South African astronomical community. It clearly demonstrates the success of the capacity-development programmes in astronomy that the astronomical community in South Africa embarked on in 2003 (NASSP) and 2005 (SKA South Africa).



Science with KAT-7 and MeerKAT

The South African SKA precursor array, MeerKAT, will be the most sensitive radio telescope in the southern hemisphere ahead of the SKA. MeerKAT has committed 70% of its observing time to ten large legacy-style surveys over the first five years of operations. Academic staff in the Department of Astronomy lead four of these large legacy surveys, corresponding to an investment of approximately one-third of all the time available on MeerKAT.

The LADUMA survey (Looking At the Distant Universe with the MeerKAT Array), co-led by Dr Sarah Blyth, aims to make the deepest observations of neutral hydrogen in emission before the SKA comes online. These observations will measure the evolution of the gas content in galaxies over half the age of the universe in order to probe galaxy evolution over cosmic time.

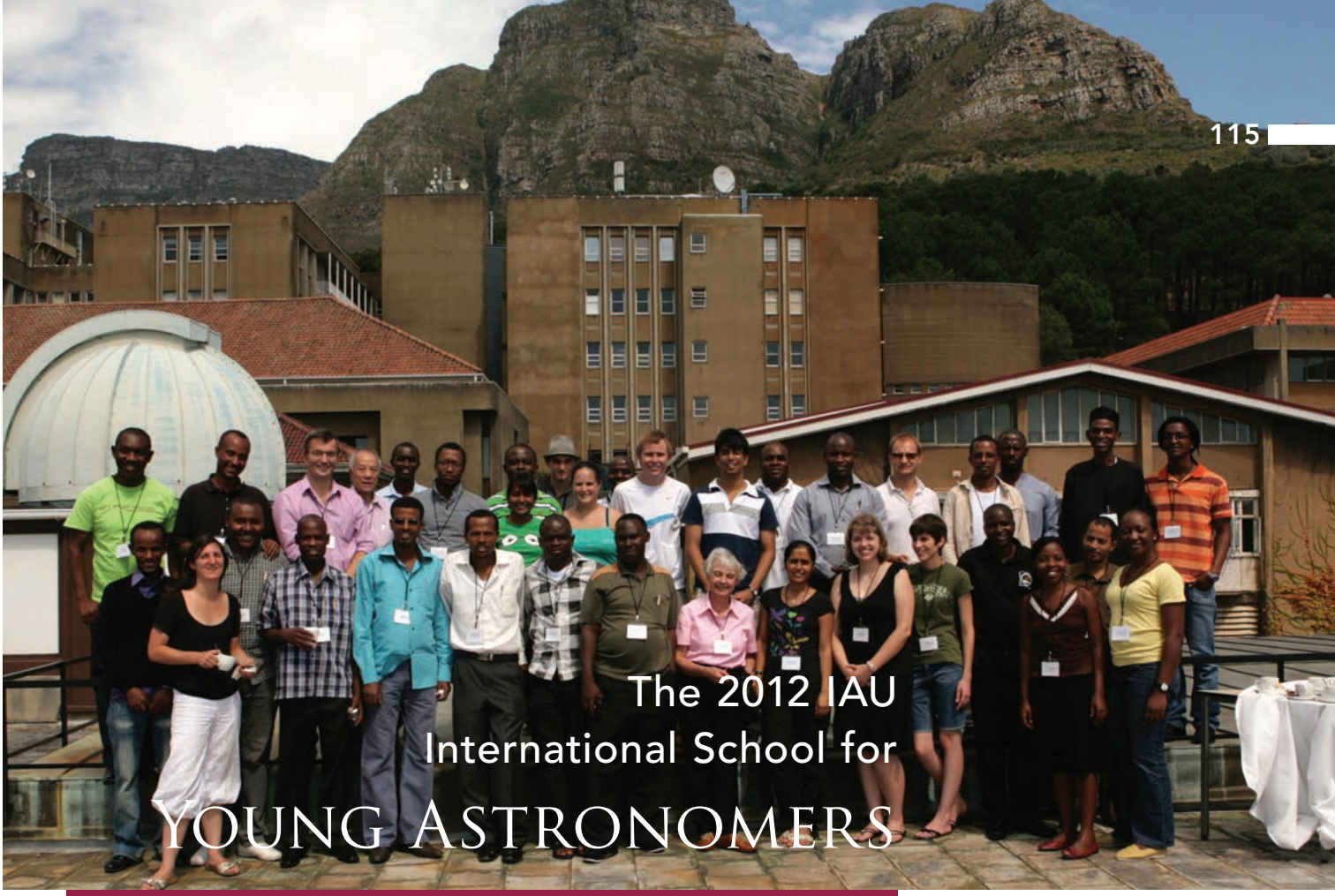
The MIGHTEE survey (MeerKAT International GigaHertz Tiered Exploration), co-led by Dr Kurt van der Heyden, is a deep radio continuum survey, which will investigate the relation of star formation to the growth of supermassive black holes as well as study galaxy evolution by detecting galaxy clusters as a function of look-back time in the universe.

The ThunderKAT survey (The Hunt for Dynamic and Explosive Radio Transients with MeerKAT), co-led by Associate Professor Patrick Woudt and Professor Rob Fender (SKA visiting professor), will study a wide range of transient phenomena in radio sources, through pointed observations of, for example, exploding stars and relativistic jets from compact stellar remnants, as well as blind searches for new kinds of transient sources.

A fourth MeerKAT large survey, MHONGOOSE (MeerKAT HI Observations of Nearby Galactic Objects: Observing Southern Emitters), led by UCT honorary Professor Erwin de Blok, will observe neutral hydrogen in nearby galaxies to investigate dark matter, properties of different galaxies, and the cosmic web.

The MeerKAT construction is ongoing and the full array of 64 radio telescopes is expected to be operational from 2016 onwards. KAT-7, a seven-dish radio interferometer built on the MeerKAT site and a precursor to the MeerKAT, is already fully operational and has started the engineering and scientific commissioning in 2012 of a wide range of observing modes.

The MeerKAT legacy surveys have been closely involved in the commissioning of the KAT-7 telescope, both to test newly developed software relevant to the surveys and to explore niche research areas enabled by KAT-7. Staff, postdoctoral research fellows and postgraduate students at UCT working on ThunderKAT and MHONGOOSE have made a number of observations during science commissioning of KAT-7 and first scientific results are being published in the international astronomical literature.



The 2012 IAU International School for Young Astronomers

From 5 to 26 February 2012, the University of Cape Town and the South African Astronomical Observatory (SAAO) jointly organised and hosted the 34th International School for Young Astronomers (ISYA), the first one held on the African continent, under the auspices of the International Astronomical Union (IAU).

This research school was aimed at MSc and PhD students from sub-Saharan Africa and attracted 32 young astronomers from a wide range of African countries (South Africa, Namibia, Ethiopia, Kenya, Nigeria, Tanzania, Uganda and Zambia). The theme for 2012 was "Observational astronomy in the optical and infrared".

Professor Anton le Roex, the Dean of the Faculty of Science, welcomed the participants to the University of Cape Town on the first day of the school, followed by welcomes by the Director of the SAAO (Professor Patricia Whitelock) and the IAU (represented by Professor Michèle Gerbaldi).

Following a week of lectures on the UCT campus, the participants continued the school at the SAAO, both in Cape Town and at the Sutherland station, where they spent one week on the various telescopes, training in aspects of observational astronomy. The observational projects were the backbone of the school, and were highly valued by the participants.

Observations by one of the lecturers (Professor Michel Dennefeld) and the IYSA students of a supernova candidate PSN J23255963-8154333 confirmed the nature of this object using the SAAO 1.9 metre telescope and spectrograph. This result was published during the school as an IAU Telegram (CBET 3028) and included the 13 IYSA students as co-authors.

Professor Renée Kraan-Korteweg elected vice-president of the International Astronomical Union

Professor Renée Kraan-Korteweg, Chair of Astronomy and Head of the Department of Astronomy at UCT, was elected Vice-President of the Executive Committee of the International Astronomical Union (IAU) at the 2012 General Assembly of the IAU in Beijing.

She becomes the third member of the Astronomy Department to have been elected to this position. This prestigious post was previously also filled by Honorary Professor Michael Feast (1979–1985) and Emeritus Distinguished Professor Brian Warner (2003–2009).

Professor Renée Kraan-Korteweg

Professor Kraan-Korteweg is a world-renowned expert in the mapping of large-scale structures hidden by the plane of our Milky Way, in relation to the dynamics and cosmic flow fields in the nearby universe. She is the principal investigator of various international collaborations and uses a multi-wavelength (combined optical, infrared, radio astronomy) approach in her research.

Her more recent efforts have focused on mapping the extent and mass of the Great Attractor, a gravity anomaly in intergalactic space that reveals the existence of a localised concentration of mass equivalent to tens of thousands of galaxies, each of which is the size of the Milky Way. A research highlight was the discovery of another major attractor hidden within the most obscured part of the Perseus Pisces Supercluster, the northern counterpart of the Great Attractor. In a project led by her, this structure is investigated in detail using new radio observations with the Westerbork Synthesis Radio Telescope in the Netherlands. The survey was designed in such a way that it will serve as a preparation for SKA Pathfinder HI surveys.

Professor Claude Carignan

Multi-wavelength Astronomy at UCT

Professor Claude Carignan currently holds the South African Square Kilometre Array (SKA) Research Chair in Multi-wavelength Astronomy in the Department of Astronomy. Recruited from the University of Montreal (Canada) in 2011, he is also an Emeritus Professor at the Laboratoire d'Astrophysique Expérimentale of the Département de physique of the Université de Montréal, and Associate Professor in the Laboratoire de Physique et Chimie de l'Environnement and in the Observatoire d'Astrophysique de l'Université de Ouagadougou, both in Burkina Faso. He has also been very involved in the development of astronomy in Burkina Faso and in the setting up of the African Astronomical Society (AfAS) in that country.

Professor Carignan is an expert on galaxy dynamics and dark matter and specialises in the study of the mass distribution in galaxies, using both radio synthesis and optical Fabry-Perot interferometric techniques. His primary contribution to research in Astrophysics has been the study of the mass distribution in late-type spiral and dwarf galaxies, carried out in the last twenty-five years. His research in this area has demonstrated that the contribution of dark matter to the total mass of dwarf galaxies (~90%) is much more important than in massive spirals (~50%). Moreover, contrary to the situation in spirals where dark matter contributes mainly in the outer parts, dark matter in dwarfs contributes at all radii. This is demonstrated for the galaxy DDO 154, now a prototype of its class. Most of this work was done using radio HI kinematical data.

Astrophysics and Space Science

Professor Thomas Jarrett has held the DST/NRF South African Research Chair in Astrophysics and Space Science in the Department of Astronomy since mid-2012. Professor Jarrett is an internationally renowned researcher who was based for more than 20 years in the United States as a mission scientist at the Jet Propulsion Laboratory of the California Institute of Technology, specialising in star-formation and extragalactic studies using space-borne instrumentation.

Leading or co-leading over 125 peer-reviewed articles in high-impact journals, his research efforts have focused on key elements of extragalactic science. Travelling to locations spanning the globe, he employs in his fieldwork ground-based, airborne and space-based observatories and remote-sensing instrumentation to gather data for analysis of the physical processes that govern the cosmos. His expertise with infrared astronomy spans the entire window: from the near-infrared (1 to 3 microns) that is used to study the stellar mass of galaxies, to the mid-infrared (4 to 50 microns) that is sensitive to star-formation and interstellar medium processes, and the far-infrared (50 to 500 microns) which traces the coldest and most massive gas and dust content of galaxies. His most recent article that highlights this research, entitled *A Cosmic Perspective, Multi-wavelength Astrophysics*, will be published in the Spring issue of the South African *Quest* magazine.

In anticipation of the SKA Era, Professor Jarrett's research has also exploited the unique capabilities of the radio window to study continuum (3, 6 and 20 cm) and 21 cm hydrogen line emission by galaxies. Combining information from a plethora of multi-wavelength instrumentation, he will explore the interconnection between the gas reservoir, as traced by HI (atomic hydrogen) observations, and the tracers of past-to-present galaxy evolution as measured using ultraviolet, visual, infrared and sub-millimetre observations. In conjunction with these themes, Professor Jarrett is a founding or key member of a number of large-science teams, including Spitzer (the fourth and final of the NASA Great Observatories programmes) and WISE (NASA's Wide-field Infrared Survey Explorer), and is an active science-team member of a number of studies, including the SKA-Pathfinder studies and MeerKAT key-science projects.

Professor Jarrett currently supervises three postdoctoral research fellows, one PhD student and two MSc students. He is currently actively involved in the development of a long-term strategy plan for astronomy in South Africa.

Professor Thomas Jarrett

Cosmology at UCT Tackling the

Mysteries Of The Universe

We live in a unique time in the history of science. Cosmological observations are able to pinpoint with great precision details of the universe on the largest scales, while particle physics experiments probe the nature of matter on the very smallest scales with equally astounding precision. Research in cosmology lives at exactly the dual point – developing the theory from a fundamental mathematical framework and testing it in a plethora of experiments and observations requiring sophisticated statistical knowledge. This is at the heart of the research undertaken by the different cosmology-related research groups at the University of Cape Town, which is striving to gain an understanding of our universe that to previous generations would have seemed perhaps unknowable.

The significant results of the Planck satellite, released in early 2013 by the European Space Agency, revealed the most precise map of the ancient universe ever made. Scientists believe these results are matched only by the groundbreaking discovery of the first fundamental scalar particle at CERN during 2012. The map has already led to new theories of the age, composition and future of the universe. The coming decades thus promise a great synergy between particle physics and cosmology as the international community at large grapples with some of the greatest unsolved problems of our time. These questions cannot be tackled by one discipline alone, and the move to interdisciplinarity is a global phenomenon. At UCT it has swept together key research groups who work together towards answering only the biggest questions about space and time. The synergies amongst these groups are generating a vibrant and interactive research culture.

At the heart of this research is the UCT-accredited Astrophysics, Cosmology and Gravity Centre (ACGC). The ACGC has 20 academic members from the faculty, and includes a DST/NRF SKA Chair held by Professor Claude Carignan and a DST/NRF SARChI Chair held by Professor Thomas Jarrett. The Centre is also particularly strong in its development of young scientists, with more than 20 postdoctoral research fellows and over 30 graduate students at any given time.

Within the ACGC, the Cosmology and Gravity Group, hosted in the Department of Mathematics and Applied Mathematics, focuses on both observational aspects of cosmology and theoretical cosmology. The Cosmology and Gravity Group is renowned for challenging the standard paradigm and proposing tests to the standard concordance model of cosmology. This is particularly pronounced in studies of the Dark Universe.

All of the substance making up planets, stars and oceans is fractional compared to the vast amount of the universe that is dark, quite literally – not observed through the electromagnetic field.

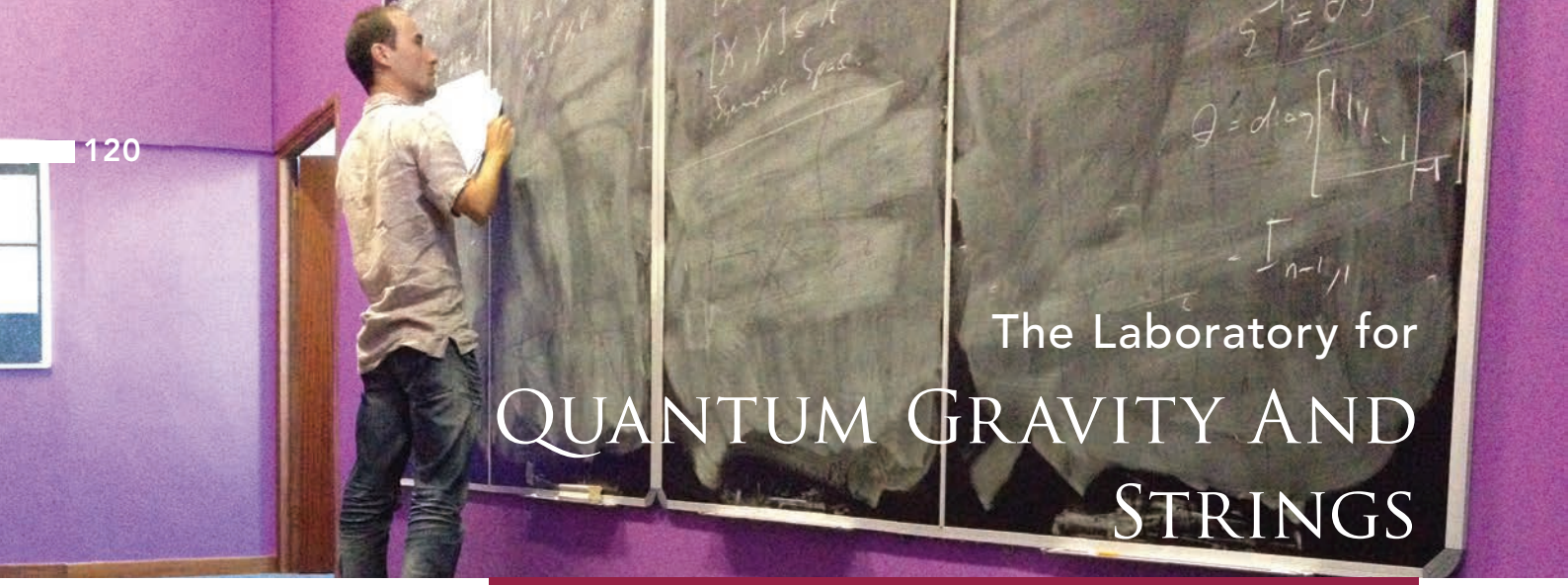
Everything we see and experience on all scales of human experience makes up less than 5% of the total matter in the universe. All of the substance making up planets, stars and oceans is fractional compared to the vast amount of the universe that is dark, quite literally – not observed through the electromagnetic field. The remaining 95% is split between Dark Matter (DM – 23%) and Dark Energy (DE – 72%).

DM clusters and DE clusters can be inferred from their effects on galaxy rotation curves as well as on gravitational lensing. DE drives the universe to expand ever faster with time – the observation of which earned scientists in the field the Nobel Prize for Physics in 2011. Remarkably, there is no convincing explanation of either the driving force behind DE or indeed the coincidental timing. DE seems to dominate our universe coincidentally around the era of humanity's existence, when we are here to observe it as such.

Explaining these observations and indeed challenging the status quo is all in a day's work for UCT's cosmologists. Alternative explanations to this concordance model are studied using a multipronged approach to test if our application of Einstein's General Relativity Theory is applicable on the scales considered by testing key assumptions underlying all of present day cosmology. UCT's Dr Chris Clarkson, Emeritus Professor George Ellis, Professor Charles Hellaby, Professor Peter Dunsby and Dr Amanda Weltman all study different approaches to this challenge.

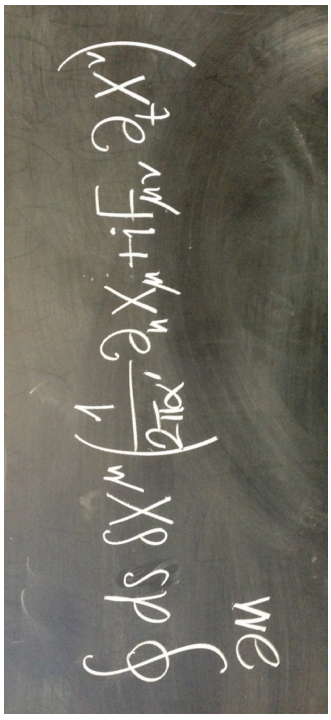
Collaborations between members of the Cosmology and Gravity Group (Professor Ellis) and the recently established Laboratory for Quantum Gravity and Strings (QGaSLab) (Dr Jeff Murugan) have resulted in a publication on the trace-free Einstein equations as a viable alternative to general relativity, selected by the journal *Classical and Quantum Gravity* as one of the 'Highlights of the 2011–2012 collection'. In addition, Professor Ellis contributed another highlight to this collection with his 2012 work 'Inhomogeneity effects in cosmology'. The group is renowned not just for challenging the standard paradigms of modern cosmology but also for offering viable alternatives. In particular, the Chameleon particle, a compelling and testable DE candidate that can be observed not only through its effects on the largest scales but also in purpose-built laboratory experiments, was pioneered by UCT's Dr Weltman. Research in this area has driven a new industry in DE testing with significant investment internationally. A flurry of experiments has ensued in the USA and Europe to test this theory, with Dr Weltman playing a key role in the GammeV and GammeV CHASE experiments at Fermilab, a US Department of Energy national laboratory specialising in high-energy particle physics.

Dr Amanda Weltman and Dr Albert van Jaarsveld, CEO of the National Research Foundation



The Laboratory for Quantum Gravity And Strings

What if the world you take for granted around you, the air you breathe, the buildings, the trees, the universe, the very space and time you occupy were not real? Not "not real" as in a dream but "not real" as in not fundamental, not a permanent stage on which the cosmology of the universe unfolds. What if everything we perceive emerged from the billions and billions of quantum interactions that ultimately and collectively resulted in the classical world we see around us. Before one ridicules the idea as the philosophical ramblings of idle academics, it is worth noting that precisely this picture leads to the emergent macroscopic behaviour of water from its underlying microscopic, molecular constituents and more and more evidence points to a very similar picture of human intelligence as an emergent phenomenon arising from the billions and billions of interactions in the intricate synaptic circuitry of the human brain.



These questions of the fundamentality of space, time, geometry and topology are exactly the kind of mind-bending mental gymnastics that occupy researchers in the newly formed Laboratory for Quantum Gravity and Strings (QGaSLAB). Located in UCT's Department of Mathematics and Applied Mathematics, QGaSLAB forms the third node of the Astrophysics, Cosmology and Gravity Centre. The laboratory is currently headed by Dr Jeff Murugan with affiliate members Dr Amanda Weltman (joint with CGG) and Dr William Horowitz (joint with UCT's Department of Physics). They are joined by Dr Jonathan Shock, recently recruited from the Max Planck Institute for Gravitational Physics in Munich, Germany.

In addition to faculty members, QGaSLAB includes current postdoctoral research fellows Dr Per Sundin (Claude Leon Fellow, formerly of Humboldt University) and Dr Michael Abbott (formerly of the Tata Institute for Fundamental Research), Dr Sugumi Kanno (joining from Tufts University in late 2013 and joint with ACGC), as well as two PhD students, three MSc students and two honours students. The group is one of only two string theory groups in South Africa and is already well recognised internationally. It is currently, together with the University of the Witwatersrand and CERN, one of the only non-EU members of the EU COST network grant "The String Theory Universe".

Research in the group is focused on four major themes: integrability, the emergence of spacetime, strongly coupled Quantum Field Theory and string theoretic physics.

Astrophysics, Cosmology and Gravity Centre

The Astrophysics, Cosmology and Gravity Centre (ACGC) is a research centre incorporating members of the UCT Department of Astronomy and the Cosmology and Gravity Group from the UCT Department of Mathematics and Applied Mathematics. The ACGC aims to create a research environment at UCT in which South African-led cutting-edge science projects will be discussed, developed and taken to fruition. Maximising the opportunities for interaction between theorists and multi-wavelength observers is essential for stimulating new approaches to research. The centre also aims to become an attractive location for postgraduate students and postdoctoral research fellows, as well as international visitors.

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Centre for Theoretical and Mathematical Physics

The Centre for Theoretical and Mathematical Physics (CTMP) is an interdepartmental research unit devoted to the promotion of interdisciplinary research in these areas. CTMP is part of the National Institute of Theoretical Physics. CTMP has twelve local members from the departments of Astronomy, Mathematics and Applied Mathematics, and Physics. It also has five international members who visit the centre on a regular basis. Postgraduate students doing theses on related research fields are admitted to CTMP for the duration of their studies. An international advisory board of seven internationally acclaimed scientists was appointed in 2006.

Director: Professor I Barashenkov
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UCT-CERN Research Centre

The UCT-CERN Research Centre was established in 2003 out of a confluence of certain research programmes within the Department of Physics. As implied by the name of the centre, there is extensive collaboration with CERN, the European Centre for Particle Physics, which is one of the most prestigious research laboratories in the world. In particular, the UCT-CERN Research Centre has close collaboration with the next-generation ultra-relativistic heavy-ion experiment at CERN's Large Hadronic Collider (LHC), named ALICE (A Large Ion Collider Experiment).

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