Cutting Edge Scientific Researches With The Most Powerful Radio Telescopes—A survey

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This is a survey of current cutting edge scientific and engineering research projects which associated with the design, construction and utilization of the most powerful radio telescopes around the world, such as SKA/MWA, LOFAR, ALMA, FAST, VLA, VLBI, VLBA, etc.

1 Introduction

2 The Square Kilometre Array (SKA)[1]

SKA project is an international effort to build the world's largest radio telescope, with eventually over a square kilometre (one million square metres) of collecting area. The scale of the SKA represents a huge leap forward in both engineering and research & development towards building and delivering a unique instrument, with the detailed design and preparation now well under way. As one of the largest scientific endeavours in history, the SKA will bring together a wealth of the world's finest scientists, engineers and policy makers to bring the project to fruition.

2.1 The key science goals

The SKA will be able to conduct transformational science, breaking new ground in astronomical observations. SKA scientists have focussed on various key science goals for the telescope, each of which will re-define our understanding of space as we know it.

From challenging Einstein's seminal theory of relativity to the limits, looking at how the very first stars and galaxies formed just after the big bang, in a way never before observed in any detail, helping scientists understand the nature of a mysterious force known as dark energy, the discovery of which gained the Nobel Prize for physics, through to understanding the vast magnetic fields which permeate the cosmos, and, one of the greatest mysteries known to humankind ... are we alone in the Universe, the SKA will truly be at the forefront of scientific research.

Early science observations are expected to start in the mid-2020s with a partial

array.

From [2]: The SKA aims to solve some of the biggest questions in the field of astronomy.

The unprecedented sensitivity of the thousands of individual radio receivers, combining to create the world's largest radio telescope will give astronomers insight into the formation and evolution of the first stars and galaxies after the Big Bang, the role of cosmic magnetism, the nature of gravity, and possibly even life beyond Earth.

If history is any guide, the SKA will make many more discoveries than we can imagine today.

The science key drivers for the SKA have been broken down in to key categories, each of which has its own working group to facilitate and manage the scientific goals.

Some Of The Main SKA Science Drivers Include:

2.1.1 Galaxy evolution, cosmology and dark energy

2.1.2 Strong-field tests of gravity using pulsars and black holes

2.1.3 The origin and evolution of cosmic magnetism

2.1.4 Probing the Cosmic Dawn

2.1.5 The cradle of life

2.1.6 Flexible design to enable exploration of the unknown

2.2 SKA Science Working Groups & Focus Groups[3]

The science working groups (SWGs) and Focus Groups (FGs) have developed and evolved to provide a conduit for interaction with the astronomical community. They are now intended to cover all science areas that will be addressed with the SKA. Inevitably there is some level of overlap between the groups, and their titles are unable to capture all the science areas that the groups cover, please see individual pages for full details of what science is covered by

each group.

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2.2.1 Cosmology

2.2.2 Gravitational Waves

2.2.3 Cradle of Life

2.2.4 Epoch of Reionization

2.2.5 Extragalactic Continuum (galaxies/AGN, galaxy clusters)

2.2.6 Extragalactic Spectral Line

2.2.7 HI galaxy science

2.2.8 Magnetism

2.2.9 Our Galaxy

2.2.10 Pulsars

2.2.11 Solar, Heliospheric & Ionospheric Physics

2.2.12 Transients

2.2.13 High Energy Cosmic Particles (Focus Group)

2.2.14 VLBI

2.3 SKA Technology[4]

2.4 Unprecedented Scale

The SKA will eventually use thousands of dishes and up to a million low-frequency antennas that will enable astronomers to monitor the sky in unprecedented detail and survey the entire sky much faster than any system currently in existence.

Its unique configuration will give the SKA unrivalled scope in observations, largely exceeding the image resolution quality of the Hubble Space Telescope.

It will also have the ability to image huge areas of sky in parallel a feat which no survey telescope has ever achieved on this scale with this level of sensitivity. With a range of other large telescopes in the optical and infra-red being built and launched into space over the coming decades, the SKA will perfectly augment, complement and lead the way in scientific discovery.

2.5 Co-hosting

Both South Africa's Karoo region and Western Australia's Murchison Shire were chosen as co-hosting locations for many scientific and technical reasons, from the atmospherics above the sites, through to the radio quietness, which comes from being some of the most remote locations on Earth.

South Africa's Karoo will host the core of the high and mid frequency dishes, ultimately extending over the African continent. Australia's Murchison Shire will host the low-frequency antennas.

2.6 A global effort

World leading scientists and engineers designing and developing a system which will require supercomputers faster than any in existence in 2015, and network technology that will generate more data traffic than the entire Internet.

2.7 Phased development

In Australia, the SKA low-frequency telescope will comprise 512 stations in a large core and three spiral arms creating a maximum baseline of 65km. Each of the stations will contain around 250 individual antennas, meaning almost 130,000 will be installed on site in total.

Initially, 476 of these stations will be constructed with a maximum baseline of 40km. The further away antennas are from the core of the telescope, the more expensive they become, so slightly reducing the number in the early stages of construction will allow the SKA to stay within the budget available at the time construction begins. The remainder will be added when funding allows.

2.8 Precursors and pathfinders

Even before the SKA comes online, a series of demonstrator telescopes and systems known as pathfinders and precursors, are already operational or under development across the world, paving the way for the kinds of technology which the SKA will need to pioneer to make the huge data available to scientists.

References

[1] SKA Organisation. The ska project. https://www.skatelescope.org/the-ska-project/, 2019 (accessed September 5, 2019).

[2] SKA Organisation. Ska science. https://www.skatelescope.org/science/, 2019 (accessed September 5, 2019).

[3] SKA Organisation. Ska science working groups & focus groups. https://astronomers.skatelescope.org/science-working-groups/, 2019 (accessed September 5, 2019).

[4] SKA Organisation. Ska technology. https://www.skatelescope.org/technology/, 2019 (accessed September 5, 2019).