The Square Kilometre Array (SKA)
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Philip Diamond, SKA Director-General

Abstract
The SKA is the next-generation radio-telescope. It will be, once complete, the largest scientific facility on Earth, with antennas spread across several thousand kilometres on two continents (Africa and Australia) and generating data volumes greater than ten times that produced by the entire internet traffic of the planet. The SKA is being designed as a physics machine for the 21st Century and will address scientific questions such as the nature of gravity, the origins of the Universe and the origins of life.

The Science Case for the SKA
The SKA science case was originally defined ~10 years ago in a major volume edited by Carilli and Rawlings (2004). In a very recent meeting in Sicily (*Advancing Astrophysics with the SKA, 9-13 June 2014)* the scientific case for SKA was refreshed and extended.

Astronomers have identified five key science areas in which the SKA will have a unique or transformational impact on fundamental physics and astronomy:

- The SKA will investigate the nature of gravity and challenge the theory of general relativity. Pulsars, the collapsed spinning cores of dead stars, will be monitored to search for gravitational waves – ripples in the fabric of space-time. The SKA will also use pulsars to test general relativity in extreme conditions, for example close to black holes.
- The Square Kilometre Array will study the detailed properties of the first luminous objects in the universe, and be able to take snapshots of the red-shifted 21 cm emission of atomic hydrogen, the most common element in the Universe, at many different epochs, before, during and after reionisation, yielding detailed information about the formation of the first structures in the universe. It will provide the tools for detailed tomography and characterisation of the first light sources in the universe.
- Atomic hydrogen emission will be detectable in normal galaxies to high redshift, providing measure of the cosmic evolution of HI and star formation. Radio continuum tracing star formation will be detectable to arbitrary redshift and the wide-field of view capability will trace out the large scale distribution of galaxies to high z, allowing precise studies and determination of the equation of state of dark energy.
- Through surveys of radio polarisation the SKA will explore the origin and evolution of cosmic magnetism. Polarized synchrotron radiation arises from relativistic particles interacting with magnetic fields. Faraday Rotation Measure synthesis (the measurement of the rotating linear polarisation vector) will be possible for more than 10^8 polarized extragalactic radio sources out to cosmological distances, allowing the evolution of magnetic fields in galaxies to be traced over cosmic time.

- The Cradle of Life: Sub-AU imaging of thermal emission originating from pebbles and small rocks will trace the process of terrestrial planet formation SKA will also search for the molecular signatures of pre-biotic molecules that are the building blocks of life. The raw sensitivity and field of view of the SKA will allow leakage radiation to be detected from potential civilizations in planetary systems around solar type stars.

The SKA Project

The SKA Organisation (SKAO) currently has 11 members (Australia, South Africa, United Kingdom, Germany, Italy, the Netherlands, Sweden, Canada, China, India and New Zealand), who between them fund the >€120M detailed design process. The detailed design is due to be complete in 2016 at which point, assuming funding has been approved, Phase 1 of the SKA will move to construction.

The SKA cores will be located on two extremely radio-quiet sites; one in Western Australia, approximately 800 km NNE of Perth; the other in the Karoo Desert of South Africa, approximately 800 km NE of Cape Town.

The SKA will be built in two phases: SKA1, now in the detailed design phase, will consist of ~10% of the final collecting area. It is planned to begin construction of SKA1 in 2018, it will be complete in 2023 and early operations will start in 2020. SKA2, the full SKA, will then, hopefully, enter its construction phase in 2024 and be complete by 2030.

The SKA Observatory will have three components, two of which will build upon the SKA precursor projects currently under construction (MeerKAT in South Africa) or in commissioning (ASKAP in Australia). A third precursor, the Murchison Widefield Array, which is now in operation in Australia, is a low-frequency array that is testing observational and data processing concepts that will be of benefit in the design of the SKA.

Ultimately, the SKA will cover the frequency range 50MHz - ~24GHz. It will consist of two basic technologies: aperture arrays for the low frequencies (50-350MHz in SKA1; covering a wider frequency range in SKA2); and dishes for the remaining frequency range.

The three components of the SKA Observatory will be:

1. SKA1-Mid, to be built in South Africa, will consist of up to 190 15m offset Gregorian design dishes, with space for 5 single-pixel frequency bands. The array will incorporate the 64 13.5m MeerKAT dishes, producing an instrument of unprecedented sensitivity with baselines of up to 180km.
2. SKA1-Survey, to be built in Australia, will consist of up to 60 of the same dishes as SKA1-Mid but with space for up to three phased-array feed receivers, a new wide field-of-view technology. The array will incorporate the 36 12m 3-axis ASKAP dishes, producing an instrument with superb surveying characteristics with baselines of up to 50km.

3. SKA1-Low, also to be built in Australia, will consist of up to ~250,000 low-frequency dipoles. This will provide unsurpassed capabilities at low-frequency with baselines of up to 80km.

The SKA Board has set a cost-cap of €650M for the capital cost of constructing SKA1. The international design team is working to design an observatory that fits within that cap.

Conclusions

From its early beginnings in 1991, the SKA is now progressing well and work is accelerating. The project is currently on schedule to begin construction in 2018, assuming the funding is identified. Once built, it will be an instrument with the widest range of science capabilities on earth, covering fundamental physics, astronomy, precision cosmology and astrobiology.