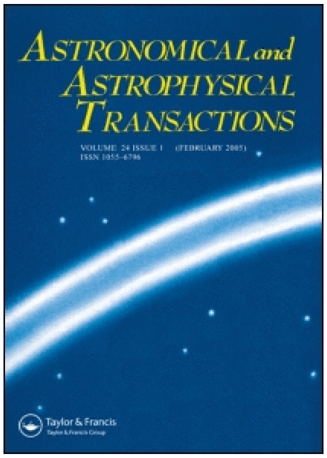

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Large-scale structure studies with a square-km array

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LARGE-SCALE STRUCTURE STUDIES WITH A SQUARE-KM ARRAY

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Preliminary studies of an interferometric radio array, having a total collecting area of one square kilometre, have been underway for the past several years in several centres around the world. The project is known by the acronym SKA (Square Kilometer Array) although there are several different acronyms that have been used for various national projects now under way. It should be noted that the term refers to the total collecting area, and not to the physical extent of the array, which will certainly be hundreds, or thousands, of kilometres.

An international body has been formed that has agreed to the following working specifications:

$A_{\rm eff}/T_{\rm sys}$	2×10^4 m^2 K^{-1}
Total Frequency Range	0.03–20 GHz
Imaging Field of View	1 squ eg @ 1.4 GHz
Number of Instantaneous Pencil Beams	100
Maximum Primary Beam Separation	1 deg @ 1.4 GHz
Number of Spatial Pixels	10^8
Angular Resolution	0.1 arcsec @ 1.4 GHz
Instantaneous Bandwidth	$0.5 + \nu/5$ GHz
Clean Beam Dynamic Range	10^6 @ 1.4 GHz

This is a partial list; for a more complete discussion see the report 'Science with the Square Kilometer Array – A Next Generation World Radio Observatory' (A. R. Taylor and R. Braun (eds.), 1999).

The SKA capability would extend our present radio sensitivities by a factor of 100 to 1000, vastly increasing the number of detectable radio sources across the spectrum from metre to centimetre wavelengths. Simulations, carried out by the Dutch group at NFRA in Ewingeloo, have shown that the resulting maps of the radio sky would be fully as rich as the celebrated Hubble Deep-Field Survey, and an investigation by Kellermann and collaborators, using the VLA, has shown that radio sources would be detected that would be beyond the reach of existing optical telescopes, including the Hubble Space Telescope. This would surely have major implications for the study of large-scale structures in the universe.

There are at least two particular fields in which the potential of the SKA for large-scale studies can be projected with certainty. The first of these, spectroscopic studies of atomic and molecular gas at very high redshift, would be implemented by having a high-frequency limit of the order of 20 GHz. Note that the SKA is not a replacement or competitor for a large millimetre-wave array such as ALMA, the project now being planned for the high Andes in Peru near San Pedro de Atacama. The special character of the SKA will be its ability to study molecular lines at redshifts of 3 to 5 and higher. Present-day instruments such as the VLA have demonstrated that the more common lines of molecules can be detected out to a redshift close to 5, and the greater sensitivity and angular resolution of the SKA would increase the power of such studies of heavy-element composition within galaxies of very young age. Atomic hydrogen, also, will be a major object of study. The redshifted 21-cm emission from the younges galaxies will be detected as they form, out to a redshift of 8 to 10. The observations will depend on the excitation temperature of the gas at this early epoch, but recent studies have shown that there is reason to expect that shock waves and radiation from Population III stars are very likely to provide the necessary spin excitation.

The study of distant gamma-ray burst sources can be expected to be another specific area in which the SKA will contribute greatly. Already, radio studies of the initial fireball associated with the gamma-ray bursters have shown that scintillation phenomena in the interstellar medium give important information on both the evolution of the source and the nature of the interstellar medium; it has been pointed out that this gives the SKA, in effect, microarc-second angular resolution. The large field of view of the SKA means that it can be used for identification purposes as well; once a gamma-ray burst has been detected, radio observations of the the field could start immediately, almost independent of the weather. The small number of radio burst dections so far has almost certainly been due to the relatively small collecting areas of present-day instruments. The enormous collecting area of the SKA would certainly change that situation. Every one of these extraordinarily powerful, extraordinarily distant objects in the universe should be detectable as soon as the gamma-ray satellites detect their occurrence.

There will surely be a large number of exciting possibilities that will arise after the SKA is built (the time frame 2012–2015 is a reasonable expectation for completion). Preliminary ideas are being actively explored now, and laboratory development work is proceeding on advanced engineering concepts. The project has started the formation of an international steering group that will evolve in time into an international management group. International agreement on a specific concept is planned for 2004, and after work on engineering models has advanced sufficiantly, the actual construction would begin. More international partners will surely be welcomed, to give the project its greatest possible intellectual and financial depth of support. Time is of the essence; 2004 seems a long time away, but choosing a site, Crafting the complex international agreements, finding the substantial funding that will be required, solving the many technological problems, and setting up a working management structure will guarantee that the next five years will be busy ones.