J. Astrophys. Astr. (2016) 37: 40
DOI: 10.1007/s12036-016-9416-7

Editorial

Radio Astronomy probes our Universe through naturally produced electromagnetic radiation in the radio frequencies. Such radiation can originate from specific astrophysical objects (e.g. pulsars, radio galaxies, active galactic nuclei), as well as from matter not specifically associated with any object (e.g. the cosmic microwave background radiation). This field has witnessed tremendous progress over the last century, allowing astronomers and physicists to study a large variety of astrophysically interesting phenomena. As is true in many other fields of astronomy, much of these studies and our understanding have been driven by the development of a number of radio telescopes all around the world, including India.

The future of radio astronomy lies in developing newer telescopes that have capabilities well beyond what is available at present. We have reached the stage today where the next generation radio astronomy facilities are so large that planning, designing and building them requires international collaborations, with astronomers and engineers from many different countries and funding agencies coming together to work on the projects. Perhaps the most prominent and ambitious of these next generation facility is the Square Kilometre Array (SKA) which is being developed by an international collaboration consisting of ten countries, India being one of them. In fact, India has been associated with the SKA from the beginning, contributing significantly to the early plans. This association has been strengthened recently when India joined the SKA Organization as a full member in 2015. The first phase of the SKA, called the SKA1, is currently in the design phase with construction expected to start within the next couple of years, i.e., around 2018. Indian astronomers and engineers, alongwith industry partners, are involved in several of the SKA design work packages. Early science with the SKA1 is expected to be possible from around 2022. So it is natural that Indian scientists are looking to enhance their scientific contribution to the SKA, and also to build up a base of astronomers that will be prepared to use the facility when it is ready.

SKA related initiatives in India are overseen by the 'SKA India Consortium' which has over a dozen member organizations from all over the country. In particular, the science initiatives in different areas are coordinated by the SKA India Science Working Groups (SWGs), somewhat in line with what is being done by the SKA Office for the international science community. These Indian SWGs have been instrumental in creating awareness related to the SKA within the Indian scientists by organizing talks, workshops, meetings etc. The number of scientists interested in the SKA has grown substantially over the last couple of years. The Indian SWGs have not only been able to attract radio astronomers, but also astronomers working in other wave bands and theoreticians interested in model building and signal predictions.

The capabilities of SKA1 will be phenomenal, for a variety of science goals and applications, and will far surpass that of any existing or planned radio astronomy facility. It will consist of two main components, namely, the SKA1-LOW to be built in Australia and SKA1-MID in South Africa.[1] The SKA1-LOW will essentially be a set of 512 'stations' each consisting of 256 log-periodic dual-polarized antenna elements. These stations will be distributed in a way that about 50% of the collecting area will be in a core of ∼500 m radius, with maximum baselines extending to about ∼65 km. The operating frequency will be about 50–350 MHz. The SKA1-MID will be consisting of 133 offset Gregorian dishes of 15-m diameter, and 64 antennas of 13.5-m diameter from the MeerKAT (which is one of the SKA precursors). The antennas will be arranged in a compact core with a radius of ∼500 m, a further two-dimensional array of randomly placed dishes out to ∼3 km radius, thinning at the edges. In addition, there will be three spiral arms extending to a radius of ∼80 km from the centre. The SKA1-MID will initially operate at frequencies from 350 MHz to 13.8 GHz.

The goals for the SKA1 cover a wide range of research areas starting from understanding the formation of stars using hyperfine transition of neutral hydrogen, to testing Einstein's theory of general relativity using pulsars, to detailed understanding of some of the early phases in the life of the Universe. At present, the international community is busy in developing up the so-called 'Key Science Projects' (KSPs), i.e., large scale collaborative projects addressing key scientific questions. Keeping in line with the above, Indian astronomers too are looking to build up their science cases so that they are in a position to play significant roles in the appropriate KSPs of interest. The first task along these lines has been to prepare a set of articles highlighting the science areas which Indian scientists are interested in, and also to provide initial plans for what they would want to do with the SKA. Various scientists have been working on preparing these science articles for quite some time now, and this Special Issue of the *Journal of Astrophysics and Astronomy* is essentially the collection of all such articles. As one will see, the Issue contains articles covering a wide range of science areas, almost all areas that are being explored by the SKA international community.

The first article of the collection by **Sushan Konar *et al.*** discusses the science areas related to neutron stars to be explored by the Indian community with the SKA1. The article also focusses on possible synergies with other existing and upcoming telescopes in different wave bands. Given that the catalogue of neutron stars are expected to be enriched by an order of magnitude, it is essential to devise novel statistical methods to analyse the data. A discussion on such statistical techniques with regard to various science cases have been presented in the next article by **Mihir Arjunwadkar *et al***.

The SKA, with its unprecedented sensitivity and angular resolution, is expected to play a significant role in shaping our understanding of the star and planet formation from the molecular gas residing in the interstellar medium. The article by **Manoj *et al.*** discusses some of the science cases that the Indian community on star formation are interested in pursuing with the SKA1.

The observed transient radio sources are usually compact in nature and are associated with explosive and dynamic events. The study of fast transients, e.g. Fast Radio

[1] http://astronomers.skatelescope.org/wp-content/uploads/2016/05/SKA-TEL-SKO-0000002_03_SKA1SystemBaselineDesignV2.pdf

Bursts, is likely to be a significant area of research with the SKA because of its wide field-of-view and high sensitivity. The interests of the Indian community in this area has been summarized in the article by **Yashwant Gupta *et al***. The other set of transients, i.e., the slow ones (e.g. supernovae, gamma ray bursts), too are interesting objects to be studied with the SKA. The possibility of understanding and uncovering the complex transient phenomena, particularly using multi wave band observations, is discussed by **Poonam Chandra *et al***.

Using the radio continuum to study the active galactic nuclei and radio galaxies has been one of the prominent research areas within India. The possibility of using the SKA to answer some of the unexplored science questions has been discussed by **Kharb *et al***. Along similar lines, the article by **Ananda Hota *et al.*** is based on science cases related to tracking the evolution of galaxies using low-frequency continuum radiation.

Moving on to somewhat larger scales, it is expected that the SKA will be able to reveal a few hundred to thousand new radio haloes, relics and mini-haloes, thus providing a comprehensive catalogue for studying the origin of synchrotron radiation from these sources. Such issues related to the galaxy clusters and the so-called cosmic web have been discussed by **Ruta Kale *et al***.

One of the fundamental principles of cosmology, the isotropy of the Universe, can be tested with a large sample of radio continuum sources, which is expected to be provided by the surveys carried out with the SKA. **Shamik Ghosh *et al.*** discuss the possibility of using different properties of these radio sources to constrain the anisotropy of our Universe at cosmological scales.

The SKA is expected to detect polarization from a large number of radio sources and measure their Faraday Rotation Measures through our galaxy, other galaxies and their circumgalactic medium. These measurements, along with the sensitive observations of synchrotron emission from galaxies will provide information on the magnetic field in these objects. Probes of the magnetic field using the SKA and its precursors have been explored by **Subhashis Roy *et al***.

The 21-cm radiation arising from cosmic neutral hydrogen in galaxies can be used for tracing the large-scale structure of the Universe at redshifts $0 \lesssim z \lesssim 6$. In their article, **Guha Sarkar and Sen** explore the possibility of using the 21-cm intensity mapping surveys with the SKA for cosmological studies, e.g., the dark energy parameters and the baryonic acoustic oscillations. The cross correlation of the 21-cm intensity mapping signal with various other observations, e.g., the Lyman-α forest observed in quasar spectra, can also be used as efficient cosmological probes, as has been discussed by **Guha Sarkar *et al***.

One of the primary goals of the SKA1 is to detect the redshifted 21-cm signal from the cosmic dawn and the epoch of reionization, the phase of the Universe during which the first stars were being formed and the cosmic hydrogen was being ionized by the resulting ultra-violet radiation. The theoretical models of reionization, both analytical and numerical, developed by the Indian community have been discussed by **Roy Choudhury *et al***. These models are useful for making predictions for the telescope. The anisotropies in the 21-cm signal arising from line-of-sight effects (e.g. those arising from the peculiar velocities) can be used for constraining the physics of reionization. Probing such effects using the SKA1-LOW have been discussed by **Suman Majumdar *et al***. The article by **Datta *et al.*** focusses on detecting the 21-cm signal pattern arising from neutral hydrogen around individual radiation sources. The signal is expected to contain information on the properties of the sources as well as the surrounding intergalactic medium and, in principle, is detectable with the SKA1. Finally, it must be noted that various systematics related to the telescope and the astrophysical foregrounds will pose enormous challenges while trying to detect the 21-cm signal from reionization. **Saiyad Ali *et al.*** discuss a new statistical estimator which is well-suited for detecting the signal in presence of astrophysical foregrounds and other systematics.

We hope the present set of articles will provide a clear direction, both to the international as well as the Indian community, regarding the SKA-related science areas of current interest within India. We also hope that these will enthuse more astronomers to get involved with the SKA, thus allowing the community to explore subjects beyond what has been covered here.

We would like to thank all the members of the SKA-India community who have contributed their time and effort enthusiastically to this collection of articles, and look forward to continued and increased participation from the Indian astronomy community in these endeavours.

Tirthankar Roy Choudhury
Yashwant Gupta

Guest Editors