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GUEST EDITORIAL

Awakening to the Cosmic Dawn

Edwin Hubble is credited with the discovery that distant galaxies appear to be receding from us: we live in an expanding universe. We now know that this expansion is at an ever-increasing rate – the universe is accelerating! We live in a hot Big-Bang universe that has been changing over cosmic time and the universe we live in today – in galaxies surrounded by highly ionized and tenuous gas – is very different from the early universe when all of space was somewhat like the interior of the Sun.

How do we know the geometry of the universe we live in? When Alexander Friedmann solved Einstein's field equations for a homogeneous and isotropic universe, both expanding and collapsing models were allowed. It took careful measurements of the apparent recession speeds of distant galaxies to settle on the actual model of the universe we live in and determine the parameters of the cosmological model for our universe. And these required astronomers and telescopes of quality.

Telescopes are our way of seeing the distant universe and since light does not travel across space instantaneously, the pictures they give us of the distant universe are in truth pictures of our distant past. Accelerated expansion in our knowledge of cosmology was made in the last 20 years or so thanks to COBE, WMAP and more recently the Planck satellite, which are all technological marvels of imaginative designs that have provided incredibly precise pictures of the universe just 380,000 years after the Big Bang. What we see in these visions of early times is an extremely homogeneous universe of hot ionized gas, with tiny perturbations in density that are the seeds of present-day galaxies and all of the large-scale structure. In the same two decades, the Hubble Space Telescope and very much larger optical and infra-red telescopes on the ground have been used in clever ways to look at galaxies farther and farther back in time – we now have portraits and spectra of galaxies and gas that show the evolution during the last 13 billion years of our history. The views show the changing universe and the buildup of galaxies from the nascent misshapen dwarfs at early times to the massive and regular giant elliptical and disk galaxies of today. Also revealed from spectroscopy is the increasing ionization of the gas between galaxies during these cosmic times.

It is a remarkable feat of human achievement that the generalized laws of physics we have tested in laboratories

on Earth and in astrophysical phenomena empower us with an ability to comprehend how the tiny density perturbations we see in the early universe evolved over time to form the universe of modern times. Phenomenal success in any branch of learning, notably when the consequence of progress is as universal as when the dynamical evolution of the universe and its geometry are learnt with a precision unimaginable just a few years earlier, often leaves us players in the field with a loss of purpose. What next?

At early times the Hubble expansion plunged the universe deeper and deeper into darkness and cold as the gas and radiation contents adiabatically cooled and red-shifted. In this setting, the formation of the first stars and galaxies from the clumping primordial gas was indeed an eventful time. The first starlight from the earliest objects that condensed and ignited nuclear burning at their cores dispelled the darkness, and ionizing radiation from the most massive of these stars rapidly and progressively cleared their environments of neutral gas. Geometry and dynamical evolution is an aspect of our history; more complex is the astrophysics of star and galaxy formation and their feedbacks to the gas environment that is the fabric from which they emerge. This was the cosmic dawn that happened somewhere close to half a billion years after the Big Bang. Current knowledge of events of that time is sketchy and real progress requires, once again, gaining a view to these ancient times. The next decade or two will see a concerted effort towards revealing the complex astrophysics during this daybreak.

The Raman Research Institute (RRI) in Bangalore along with international partners commenced the groundbreaking effort towards throwing light on the ending of the dark ages almost 7 years ago. The partnership is led by university groups and institutions with core competence in basic research and inherent strength in niche areas that lie in the critical path of purpose building a telescope for the problem on hand. RRI, along with Harvard and MIT in the US as well as institutions in Australia and New Zealand, has built a radio telescope in the Australian outback about 800 km from Perth in Western Australia. The digital receivers of the Murchison Wide-field Array (MWA) radio telescope were built at RRI. Engineers and scientists from RRI worked along with international partners in the remote Australian outback installing and commissioning the telescope.

RRI built a millimetre-wavelength radio telescope on its campus in Bangalore, and later partnered the building of a decametre wavelength antenna array for radio astronomy at a site close to Gauribidanur, about 80 km north of Bangalore. That confidence led to participation in a collaboration that built another radio telescope farther from home and in the Indian Ocean island of Mauritius. RRI built receivers for the Giant Metrewave Radio Telescope (GMRT), and also placed receivers atop the Green Bank Telescope in West Virginia, which is the largest steerable radio telescope in the world today. The history was the basis, it provided the inner confidence, and it also provided the external partners with the conviction that RRI could be entrusted with a key element of MWA. RRI entered into the MWA partnership assuming the responsibility to design and build the digital receivers, and that was essentially the totality of its subscription for part ownership of the telescope. RRI participation in MWA was on the strength of technical competence in the engineering and on its standing in the key science goals, as it should be.

The MWA consists of 2048 dual-polarization wideband ‘bow-tie’ antennas optimized for operation in the frequency range 80–330 MHz, arranged as 128 square ‘tiles’, each of which have 16 antennas. The tiles are spread over a 3 km area: the antenna distribution is optimized for the specific science objectives and precision imaging of a wide field of several hundred square degrees of the sky at any instant and over the wide frequency band.

With wireless communications coverage rapidly expanding across the country, most of India is no longer suitable for siting wideband radio telescopes that must necessarily operate in the broadcast bands. The MWA is placed in the Murchison shire of Western Australia – one of the most sparsely populated regions of the world that has very little radio frequency interference, which is absolutely essential for exploring deep into our cosmic history.

RRI designed and built the digital receivers. They take the signals from the antennas and perform complex high-

speed signal processing algorithms that process and condition the data and then transmit the data via optical fibres to a central processing unit where the imaging information is computed.

The MWA successfully completed its commissioning phase and has just transitioned to scientific operations. The first observing cycle is now underway and all indications are that the telescope and data are meeting the high expectations set during commissioning. The telescope has begun gathering the weak radio signals from deep space that will be analysed over the coming years by scientists at RRI and in the US and Australia using massively parallel computing systems. These analyses are expected to reveal a first glimpse at how the early universe transformed dramatically as the ‘First Light’ from the first stars and galaxies that formed in the primordial universe lit up the ‘Dark Ages’ and our universe emerged into the ‘Cosmic Dawn’.

Besides this key science goal, astronomers from across the world will, of course, use the MWA for the new visions of the cosmos that it enables. The MWA will perform several surveys of the entire southern sky and make extremely sensitive images of targeted regions. The data will provide astronomers insights into the structure of the gas in our Milky Way galaxy and of its magnetic field. Cosmic radio sources are sometimes transient in nature and sometimes periodic in their emissions: time-domain astronomy is an emerging field of research enabled by recent advances in high-speed digital signal processing capabilities and ability to process stupendous data volumes. Already hitherto unknown classes of cosmic explosions in our galaxy and beyond are being revealed. Last, but perhaps the most relevant to the existence of mankind, is the MWA potential to advance the frontiers of our understanding of space weather that connects our Sun to the environment near Earth.

The completion of MWA is a momentous step to the setting up of the international Square Kilometre Array (SKA), a massive global project to build the world’s largest radio telescope across Australia and South Africa in the coming decades. MWA is a precursor to the SKA and represents a step towards RRI’s involvement in this futuristic endeavour. This next-generation new-technology radio telescope promises to herald path-breaking advances in the deployment of distributed and massively parallel antenna technology, integrated receivers, energy systems, communications and computing. With its excellent international standing in this field, its track record of building and enabling science with world-class facilities such as the Ooty Radio Telescope, the GMRT and now the MWA, India is well poised to be a respected partner in this international partnership.



Engineers of the Radio Astronomy Laboratory of RRI on the visit of the Australian Minister for Innovation, Senator Kim Carr. (Photo credit: RRI, Bangalore)

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