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Radio telescopes
Big Astronomy

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SPDO/TDP/DRAO/Swinburne Astronomy

PARADOXICALLY, when you talk to people about “big science”, they tend to imagine the stupendous atom-smashers, cavernous underground labs and expensive international collaborations necessary to conduct modern particle physics, which is concerned with studying the very smallest slices of reality. But it is not just physicists who have a fetish for expensive machines. April 2nd saw the announcement that Jodrell Bank, a British observatory in the countryside near Liverpool, has been chosen as the headquarters of the €1.5 billion ($2.1 billion) Square Kilometre Array (SKA), a 19-country collaboration that hopes to build the biggest radio telescope ever.

Jodrell Bank has form, even if it will not be the physical home of the SKA (that honour will go to either Australia or South Africa). In radio astronomy, as in particle physics, bigger kit is better—a larger telescope can gather fainter signals and produce sharper images. Jodrell’s Lovell Telescope, with its 76m dish diameter, was the biggest steerable telescope in the world when it was built in 1957. Today it is dwarfed by the 100m Robert C Byrd telescope at Green Bank in West Virginia, which is in turn put in the shade by the enormous (but fixed) 305m Arecibo dish, built into a Puerto Rican hillside in 1963.

They are impressive machines. But the physics of radio astronomy means they are, nevertheless, relatively crude. A typical optical telescope might have a diameter a few million times the wavelength of the light it is collecting. Applying that scale to radio astronomy—where wavelengths are measured in centimetres—would require dishes several kilometres across.

Since building a dish that size is impossible, the SKA plans to use around 50,000 smaller receivers networked together into a single monstrous machine. Many of the receivers will be concentrated in an inner “core” about 5 kilometres on a side, but some will be arranged into a set of elegant spiral arms 1,500km long. Using a signal processing technique known as interferometry, the cluster of little telescopes will be able to function as one enormous, “virtual” instrument, with a receiving area equal to the combined area of the individual dishes (one square kilometre, logically enough) and a baseline (a measure of the telescope’s resolving power) equal to the distance between the furthest individual components—or about 3,000km.

Using interferometry to boost the resolving power of telescopes is an idea that dates back several decades—many of the world’s existing radio telescopes are integrated into such networks, including the Lovell Telescope (which is part of Britain’s MERLIN system). Nor is the idea of using thousands of small, relatively cheap dishes, all that new. Several existing telescopes, such as the Dutch-run Low Frequency Array, which has thousands of low-tech antennae spread across Northern Europe, or Australia’s Murchison Widefield Array, have pioneered the concept, which has other advantages besides cost and resolution—the modular nature of the telescope means that upgrading it is as simple as plonking down extra receivers. What is different about the SKA is the sheer scale. When it is finished in 2024 it will be around 50 times as sensitive as current instruments, and be able to survey the sky about 10,000 times faster. Serious computing power will be required to make sense of the torrent of data that the telescope will generate—up to 160 gigabits per second from each individual antenna.

Peering into the gloom

That power will be used to investigate some of the biggest outstanding questions in astronomy. The SKA will join the hunt for gravitational waves, ripples in the structure of space predicted by Albert Einstein’s general relativity. It will probe the mysterious magnetic field that exists between the stars, and its resolving power will help with the search for extrasolar planets.

But what really excites astronomers is the possibility of using the telescope to peer back in time into the cosmos’s "Dark Ages", a period between roughly 400,000 and 800m years after the Big Bang, before the first stars formed and about which very little is known directly. It was during the Dark Ages that the universe cooled enough to allow molecular hydrogen to form, filling the cosmos with a diffuse cloud of electrically-neutral gas. Over millions of years gravity went to work on the tiny irregularities in the distribution of that gas, condensing hydrogen into stars, stars into galaxies, and galaxies into the clusters and superclusters that make up the largest structures of the modern universe. Radiation from the newly-shining stars slowly re-ionised the remaining free hydrogen, carving ionised bubbles out of the primordial interstellar medium, a process which ultimately culminated in the re-ionisation of the entire universe around a billion years after the Big Bang. Neutral hydrogen emits radiation on a characteristic 21cm wavelength, while ionised hydrogen does not. By looking for that radiation (and, more significantly, its absence) the SKA will be able to chart some of the earliest developments in the evolution of the cosmos.

Of course before all that happens there is the small matter of deciding where the telescope will be built. The consortium is considering two bids, the first based in South Africa (with antennae extending as far away as Ghana, Mauritius and Madagascar), and the other in Australia (with some antennae in New Zealand). There is more at stake than international scientific bragging rights—although don’t underestimate the appeal of those. The host countries will be hoping that building and installing such a technologically formidable machine will boost their own high-tech industries. A decision is expected in 2012; expect plenty of discreet behind-the-scenes lobbying in the intervening months.

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