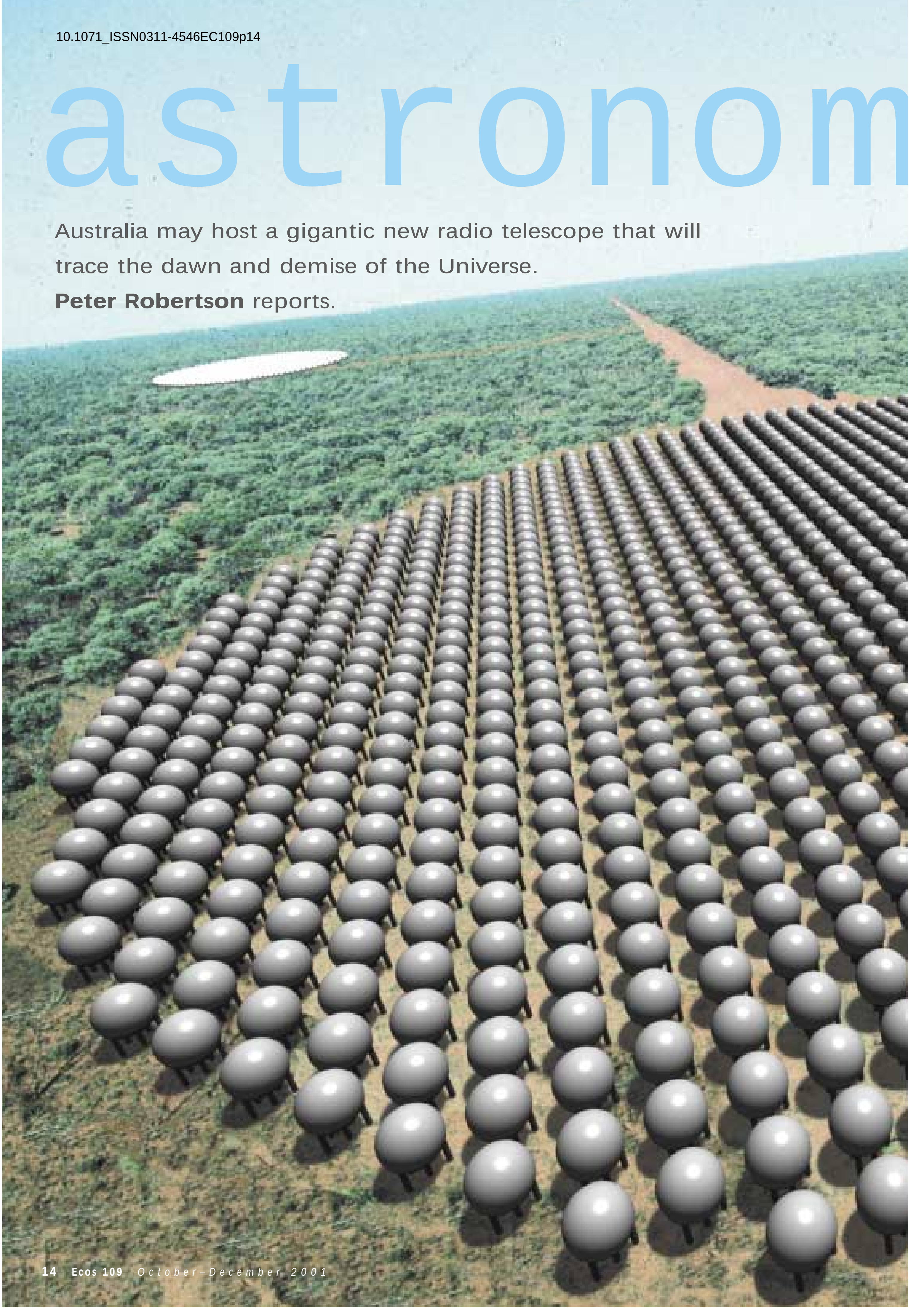
10.1071_ISSN0311-4546EC109p14

astronom

Australia may host a gigantic new radio telescope that will trace the dawn and demise of the Universe.

Peter Robertson reports.



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How the SKA might look. A computer animation shows an 'array-station' consisting of 400 Luneburg lenses, roughly equivalent to the collecting area of a 100-metre dish. The complete SKA would consist of about 100 of these array-stations, some hundreds of kilometres distant from the central cluster.

Mention the words ‘radio telescope’ and many of us think of the Parkes Telescope in New South Wales, an icon of Australian science, and star performer in the movie *The Dish*. Others might picture the giant bowl at Arecibo in Puerto Rico, as featured in the James Bond adventure *Golden Eye*.

Imagine now a radio telescope 100 times larger and more powerful than ever before; equivalent to 300 replicas of the Parkes dish: as big as the suburb or town you live in. An international consortium of astronomers is planning to build such a telescope – the Square Kilometre Array, or SKA – and Australia is high on the list of candidate locations.

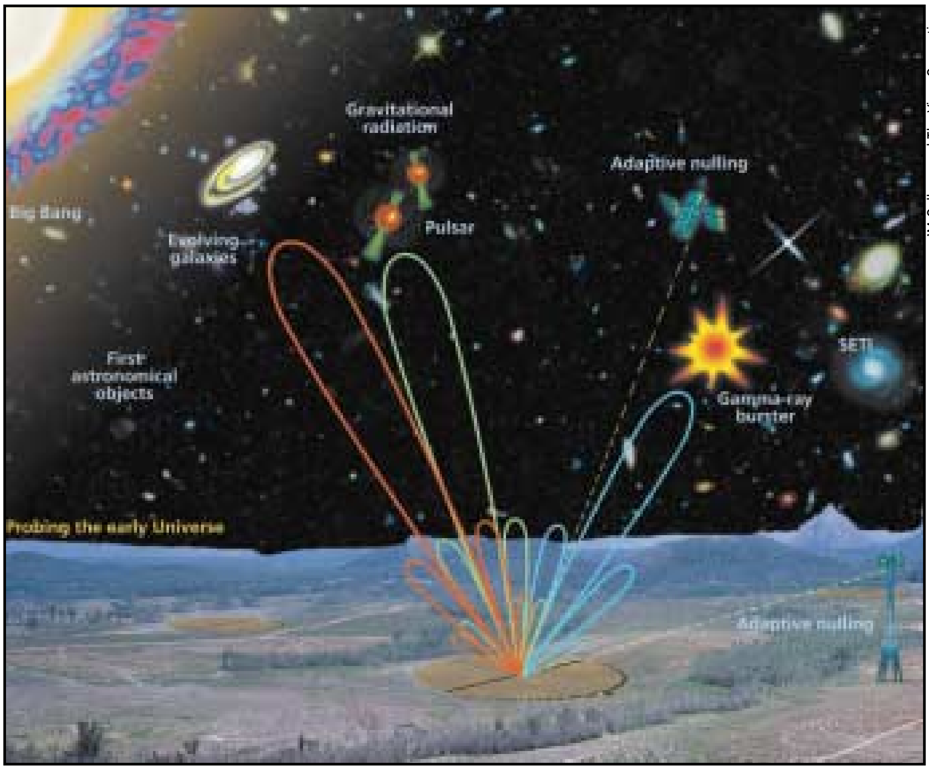
This ‘next generation’ telescope will cover one square kilometre, but unlike the Parkes dish, it won’t be a single surface, or even confined to one locality. Instead, many small antennas will collect the radio waves, their signals combined electronically into one big picture.

The array’s central mission will be to explore the childhood scribblings of the Universe: weak, distant signals emitted less than a million years after the Big Bang. These will shed light on how the first stars and galaxies came into being.

‘The SKA will reveal the emergence of structure in the early Universe, help us distinguish between competing cosmological theories, and perhaps predict the evolution and eventual fate of the Universe,’ Dr Peter Hall, SKA program leader at CSIRO’s Australia Telescope National Facility says.

‘It will tell us how ripples in the cosmic background have been transformed into the structures we know in the present Universe, such as stars and galaxies.’

The SKA will also provide more detailed pictures of known astronomical objects,



JM Colberg and The Virgo Consortium

The SKA will reveal the emergence of structure in the early Universe. This simulation shows how galaxies and galaxy clusters may have formed.

and help solve some puzzles uncovered by astronomers in recent years.

One such mystery is ‘dark matter’.

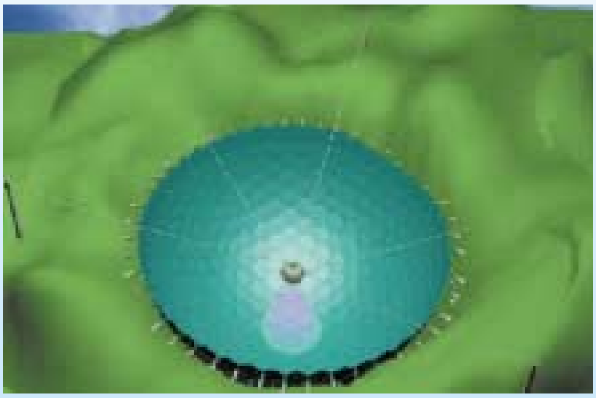
We see stars and galaxies because they shine, but there is compelling evidence that most of the matter in the Universe may be hidden from view. The array will probe the structure of galaxies to gather clues about whether dark matter exists, and whether it lurks in giant halos surrounding each galaxy.

Gravity waves – ripples in the fabric of space-time generated by black holes and other massive objects – are another great mystery. These were first predicted by Albert Einstein in his 1915 theory of general relativity, but have yet to be directly detected.

The array will study a large sample of pulsars and closely monitor the timing of the radio pulses they emit. Variations in the regularity of the pulses could be the tell-tale sign that a pulsar has been tossed about by passing gravity waves.

How common are planets elsewhere in our galaxy? A number of giant Jupiter-sized objects have already been detected orbiting nearby stars, but it may take the sensitivity of the array to detect the first small earth-like planets.

The array will also join the search for extra-terrestrial intelligence. The planetary systems of many stars will be monitored simultaneously in the hope of finding the first elusive signal that tells us we are not alone.



Antennas of CSIRO's Australia Telescope, near Narrabri, NSW. Small patches of SKA antennas will be built alongside these antennas and used to work with them, to test concepts for SKA technologies.

Closer to home, neighbouring planets will be studied in greater detail, and changes monitored in our local space weather. The array will also be able to track a host of satellites and deep-space probes simultaneously, proving its value not just to astronomy.

A global pursuit

The Square Kilometre Array project is too large to be handled by one country. This will be the first radio telescope to be 'born global', growing out of discussions at the International Union of Radio Science and the International Astronomical Union, umbrella organisations that oversee the development of radio astronomy.

An international consortium will develop and evaluate the various design concepts. So far, the consortium consists of institutions in 11 countries: Britain, Canada, China, Germany, India, Italy, the Netherlands, Poland, Sweden, the United States, and Australia. The cost of the project is expected to be more than $1 billion.

Australia has supported the project from the start, and there is now a national consortium coordinating research and development for the array. Its members include CSIRO, the University of Sydney, the Australian National University and Swinburne University of Technology.

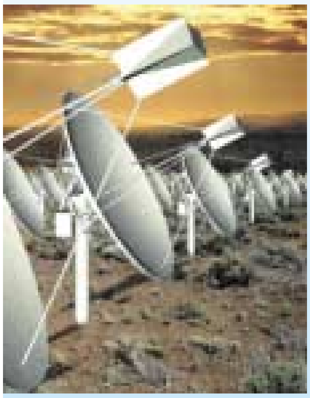
In 1999, CSIRO set up a seed program for SKA research and development, the beginning of a larger commitment that will build to 2005, the year the international consortium will choose between the various design concepts. The Australia Telescope National Facility and the Division of Telecommunications and Industrial Physics are the main CSIRO divisions involved.

In August this year, Australia's bid was further boosted by the announcement of a large government grant under the Major National Research Facilities Program.

Revolutionary design

More design concepts are under investigation than the number of countries involved, but this is deliberate. The consortium wants to investigate a wide range of ideas as a means of arriving at a revolutionary array that:

- has a high angular resolution to obtain sharp images of radio sources (with its high sensitivity, high-fidelity imaging, and excellent angular resolution, the SKA will have 20/20 vision compared with existing radio telescopes);
- operates over a much wider bandwidth than the narrow radio spectrum now allocated to radio astronomy;
- is located in a radio-quiet zone and can counteract interference from sources such as satellites and communications transmitters;



Design concepts for the array (from far left).
China is examining a series of large dishes set into natural hollows in the ground.
Canada is looking at a series of much flatter reflectors, with balloon-mounted receivers floating high above.
India and the United States are considering medium-size dishes, using new techniques of mass production.
Dutch researchers are investigating arrays of flat tiles that use clever electronics to mimic the performance of a dish.

A Russian Luneburg lens being tested by Dr Peter Hall at CSIRO's Australia Telescope National Facility in Sydney.

- has multiple fields of view so that up to 100 different observing programs occur simultaneously (conventional radio telescopes 'look' in one direction); and
- is flexible enough to take advantage of future breakthroughs the rapidly developing areas of computer and signal processing.

The design favoured by Australian astronomers consists of a close-packed group of relatively small antennas covering an area of 100-200 metres in diameter. Such a group is called an 'array-station'. The complete array will combine a large number of these array-stations, possibly as many as 100.

About half the array-stations would be clustered together in a central site of about 50 square kilometres. The others would span larger distances, as far as 2000 km from the central site. This array would produce the angular resolution required to create sharp images of radio sources.

Russian eyeballs

Australia has been investigating a type of antenna known as the Luneburg lens. In collaboration with Russian astronomers, CSIRO has obtained a small prototype lens from a Moscow-based company.

The lens acts just like an eyeball, focussing radio waves to a point in the same way that the lens in an eye focuses light to a point on the retina. Similar to the eye, the lens can 'see' many radio sources in the sky at the same time, one of the key design requirements.

The array would need tens of thousands of these Luneburg lenses, each about five metres in diameter, so ways will have to be found to mass-produce them easily and cheaply.

The Russian lens is made of high-density polystyrene foam, but CSIRO is developing lighter and cheaper materials that absorb less of the faint radio signals.

'The Luneburg lens is one of the front runners', Peter Hall, says. 'The lens is the least understood of the candidate antennas, but stands a good chance if the problems associated with the foam loss and cost can be overcome.'

If small-scale prototyping studies are successful, the CSIRO group plans to build a small array of the lenses at Narrabri in New South Wales, the site of the array of large dishes that form the Australia Telescope. The Luneburg array will be integrated into the Australia Telescope so that a range of ideas and theories can be tested.

Australia and the rest of the international consortium are in for the long haul.

After the final decisions on the design concept and the location of the telescope are made in 2005, work will begin on an advanced prototype. Construction of the mega-telescope itself is expected to start in 2010 and for the array to be operational in 2015. The telescope for the new millennium is on its way.

Abstract: Astronomers are planning to build a gigantic new radio telescope known as the SKA or Square Kilometre Array. The SKA will be 100 times larger than the current generation of radio telescopes. Australia is part of an international consortium planning the telescope. Researchers at CSIRO and several Australian universities are investigating a number of design concepts. The SKA will be used to study a wide range of problems in astronomy, in particular how stars and galaxies formed in the early Universe. Australia may be chosen as the country to host the SKA.

Keywords: Square Kilometre Array (SKA), radio telescopes, astronomical objects, astronomy, Luneburg lens.

Lure of the **outback**

THE BURNING question is: where will the Square Kilometre Array be built?

The international consortium will wait until 2005 before announcing the host country, to give the bidding countries time to prepare their case.

For Australia, the decision in 2005 may be the scientific equivalent of the announcement of Sydney as the host of the 2000 Olympics.

Australia scores well on the checklist for the ideal site for the following reasons.

- A large, mainly flat country with relatively cheap land. If the array-stations forming the SKA are to spread over 2000 km, it is better to keep them in the same country.
- A site compatible with existing land use. Open and sparsely used grazing country, national parks and reserves provide the best sites. A radio-quiet zone will be needed to minimise radio interference from human activities.
- A stable and benign climate. Snow, hail, flooding and cyclonic winds would cause havoc with the antennas and other SKA instrumentation. The storms and salt-spray of coastal regions will also have to be avoided.
- An infrastructure to support such a mammoth project. Power, water, a transport grid and advanced telecommunication networks are essential elements.
- Political stability. The SKA may take 10 years to build and may operate for another 40. Countries supporting the project need reassurance that their investment is secure.

Several countries, including the United States, will have strong claims, but the trump card for Australia might be the fact that we are south of the equator.

The best view of our galaxy – the Milky Way – is from the Southern Hemisphere and it is the Milky Way that is home to many of the objects astronomers will want to target with the SKA.

For the same reason, the United States and European nations have built several large optical telescopes in Chile, high in the clear, rarefied air of the Andes. These telescopes have a far better view of the Milky Way than sites located in the Northern Hemisphere.

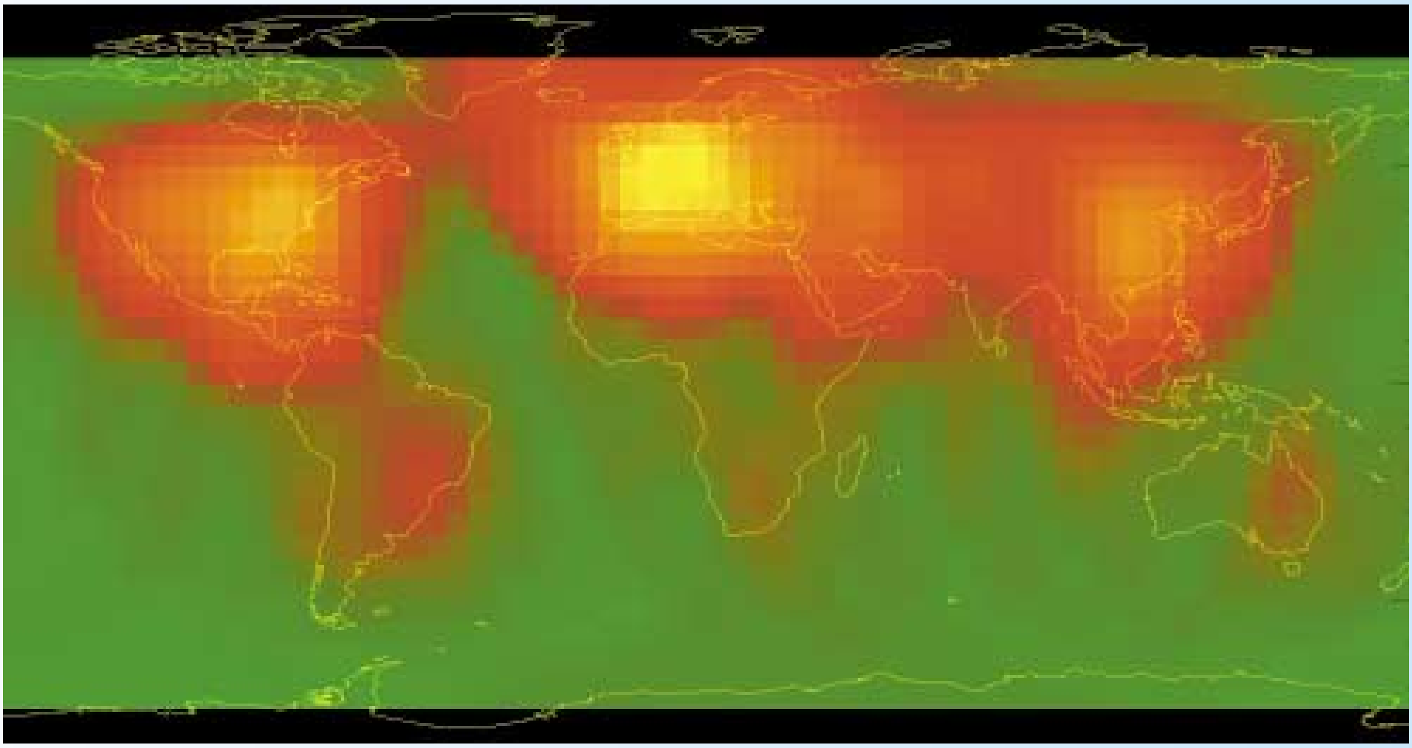
'Australia is seen as having a good chance because it combines radio quietness with political stability, as well as having a technologically sophisticated society', CSIRO's Dr Peter Hall says.

'The United State will almost certainly put in a bid, and I expect that we might see bids from South Africa, China, and perhaps Russia.'

Hosting the SKA is likely to lead to significant economic benefits.

'A recent study showed that large astronomical facilities can bring at least a two-fold return on national investment', Hall says.

'The SKA project offers significant potential for researchers and industry to capitalise on fundamental contributions in the areas of antennas, radio frequency systems and signal processing areas. Australian companies will share in the benefits of commercialising this new technology.'



Background radio emission. This image, made with data from the FORTE satellite, shows background levels of radio emission at a frequency of 131 MHz. FORTE is designed primarily to detect radio emission from lightning strikes, but it also detects human-made signals.

Radio waves from the distant cosmos are extremely weak, and easily swamped by terrestrial signals. The Square Kilometre Array telescope will need to be sited in an area that is as free as possible from human-made background radio signals. As the FORTE image shows, many parts of Australia have low levels of background radio signals, and so it would be feasible for the SKA to be sited here.