

REDISCOVERING THE UNIVERSE

We've spent the last 300 years peering at the stars through a pinhole – but now we're going to build a floodlight to see more than ever before. And it just might be located in Australia.

BY DAVID KIDD

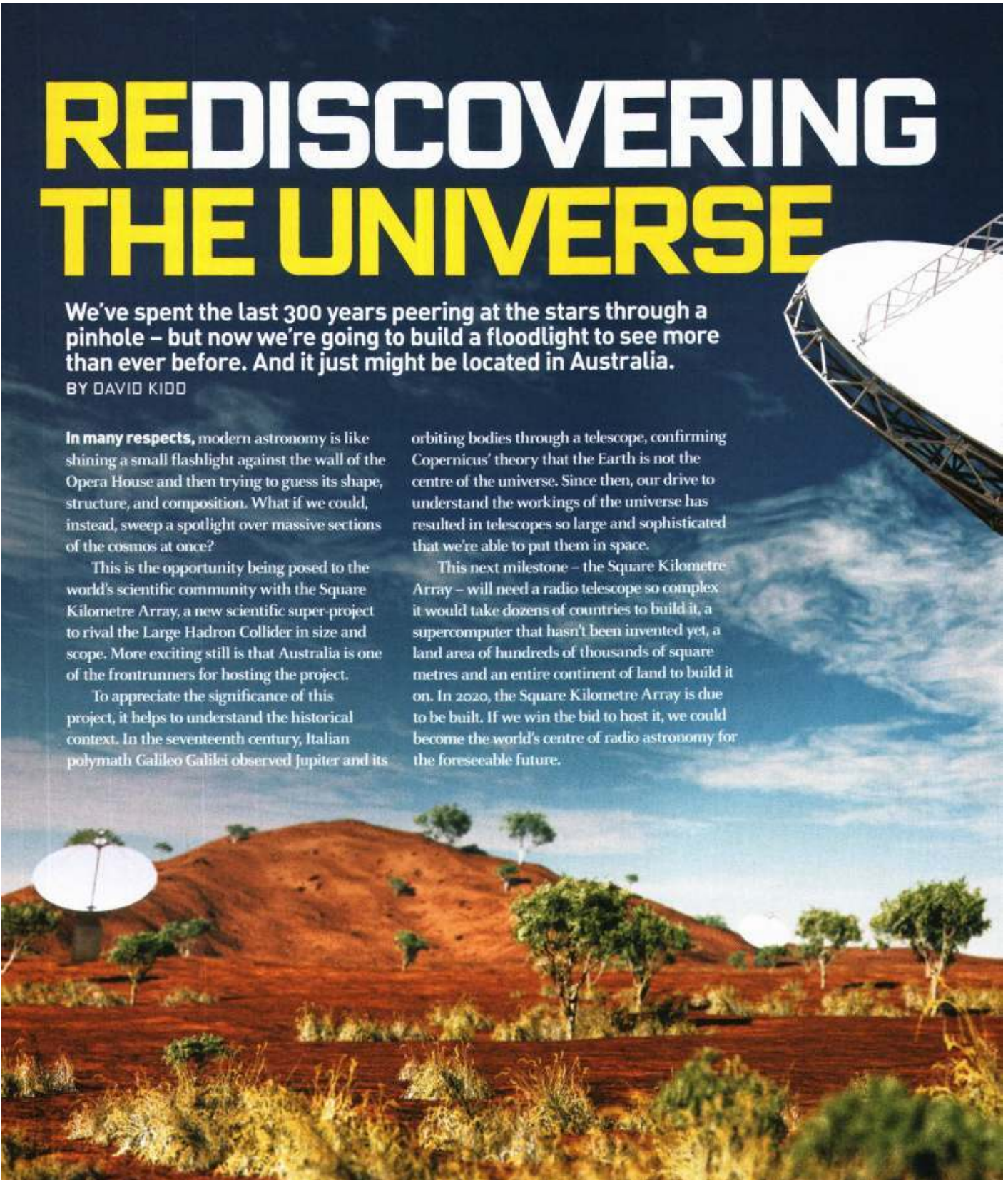
In many respects, modern astronomy is like shining a small flashlight against the wall of the Opera House and then trying to guess its shape, structure, and composition. What if we could, instead, sweep a spotlight over massive sections of the cosmos at once?

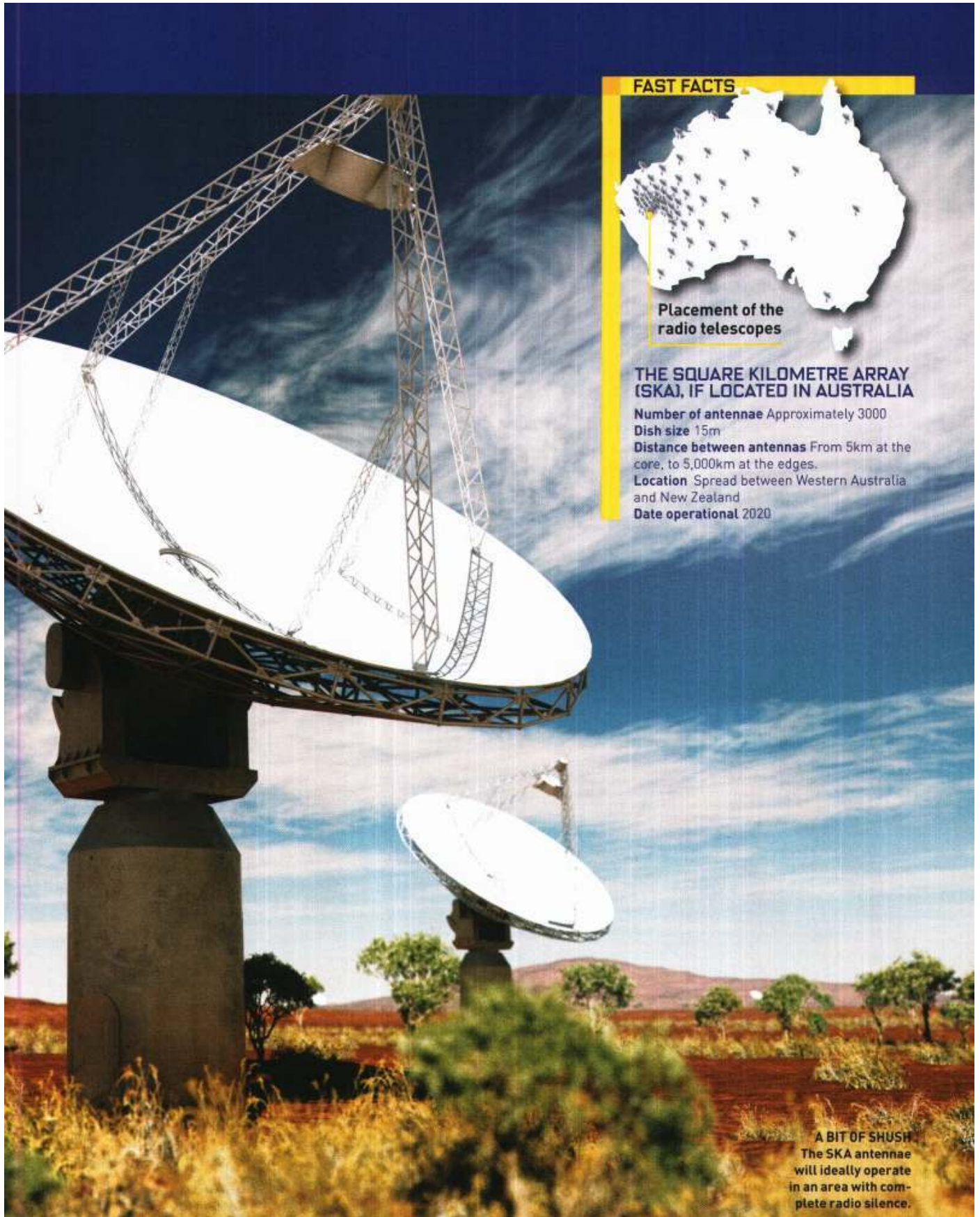
This is the opportunity being posed to the world's scientific community with the Square Kilometre Array, a new scientific super-project to rival the Large Hadron Collider in size and scope. More exciting still is that Australia is one of the frontrunners for hosting the project.

To appreciate the significance of this project, it helps to understand the historical context. In the seventeenth century, Italian polymath Galileo Galilei observed Jupiter and its

orbiting bodies through a telescope, confirming Copernicus' theory that the Earth is not the centre of the universe. Since then, our drive to understand the workings of the universe has resulted in telescopes so large and sophisticated that we're able to put them in space.

This next milestone – the Square Kilometre Array – will need a radio telescope so complex it would take dozens of countries to build it, a supercomputer that hasn't been invented yet, a land area of hundreds of thousands of square metres and an entire continent of land to build it on. In 2020, the Square Kilometre Array is due to be built. If we win the bid to host it, we could become the world's centre of radio astronomy for the foreseeable future.





FAST FACTS



Placement of the radio telescopes

THE SQUARE KILOMETRE ARRAY (SKA), IF LOCATED IN AUSTRALIA

Number of antennae Approximately 3000

Dish size 15m

Distance between antennas From 5km at the core, to 5,000km at the edges.

Location Spread between Western Australia and New Zealand

Date operational 2020

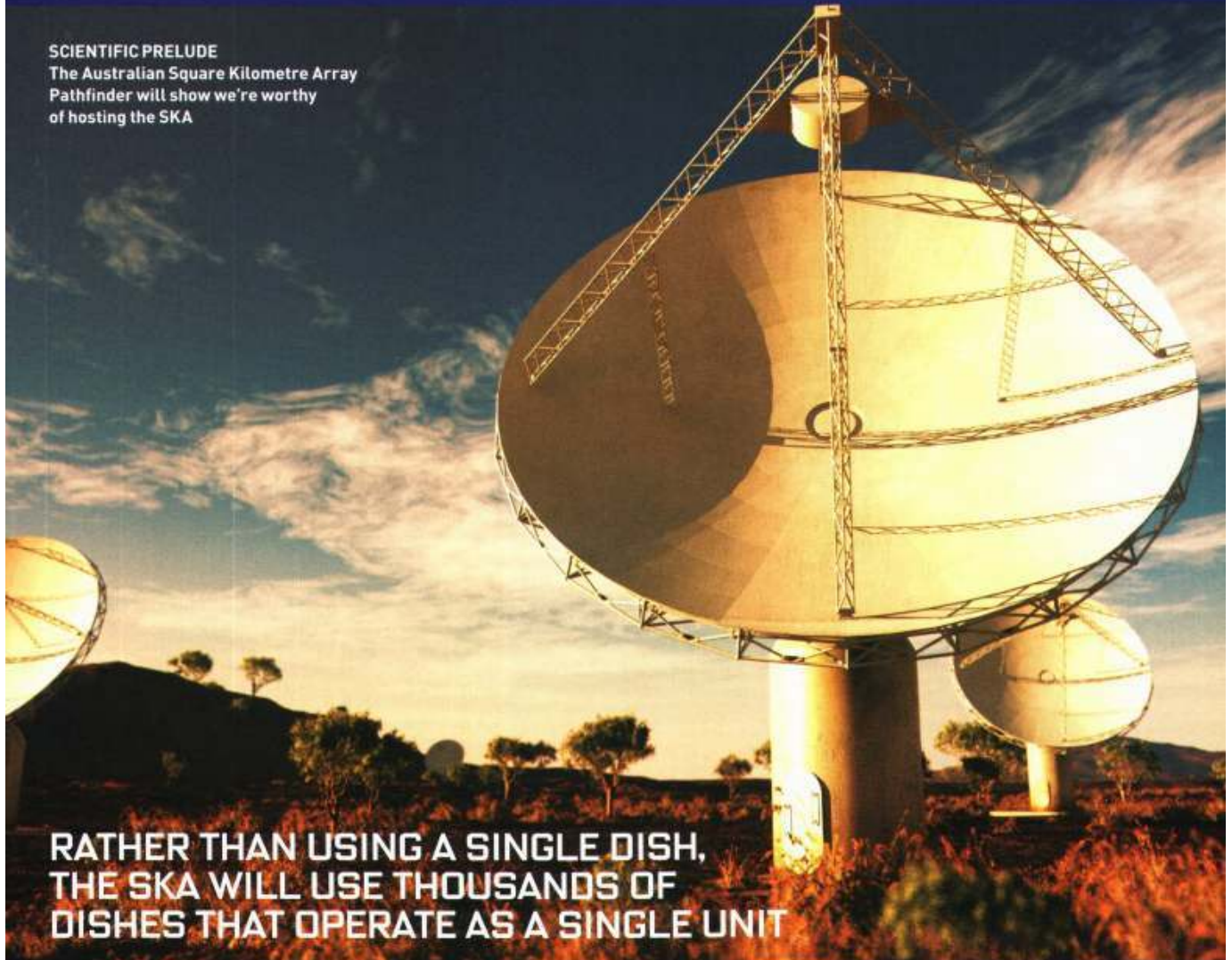
A BIT OF SHUSH
The SKA antennae will ideally operate in an area with complete radio silence.



THE FUTURE OF ASTRONOMY

SCIENTIFIC PRELUDE

The Australian Square Kilometre Array Pathfinder will show we're worthy of hosting the SKA



RATHER THAN USING A SINGLE DISH, THE SKA WILL USE THOUSANDS OF DISHES THAT OPERATE AS A SINGLE UNIT

BIGGER IS BETTER

The Square Kilometre Array (SKA) is one of the biggest ground-based astronomy projects in history, on par with the Large Hadron Collider in terms of scientific significance. However, the SKA isn't just a single project, nor is it even in one location; rather, it will be a vast network of small telescopes – around 3,000 dishes, all linked – based either in Murchison, Western Australia or Karoo, South Africa. Wherever the array is located, it is destined to have an enormous impact on astronomy.

"It's the biggest radio telescope ever envisaged," says astronomer and award-winning author Fred Watson. "There's absolutely no doubt that the SKA will do at least as much for radio astronomy as

Hubble did for optical astronomy. It ranks with the 200-inch [optical] telescope in Palermo. It's that kind of order of magnitude".

The SKA is a radio telescope, which means it can observe phenomena outside the range of optical telescopes. Cosmic radio waves can carry information relating to very distant – and, therefore, very old – interstellar objects. However, some radio waves are so faint, and at such low frequencies, that you need an exceptionally large telescope to detect them.

But, rather than using a single dish to capture the waves, the SKA will use thousands of dishes that operate as a single unit, vastly increasing its collecting area. "The SKA has a collecting area of

one million square metres, which gives it far more sensitivity than any other radio telescope in the world," says Watson.

In addition, it will also apply a technological multiplier, called 'very long baseline interferometry', which lets the array mimic a telescope of a size proportional to the distance between its antennae. And how far apart will the SKA's antennae be? Assuming Australia wins the bid, the antennae will span thousands of kilometres, spiralling out from a densely packed core in Western Australia all the way to New Zealand. All that stands in our way is South Africa – the other chief bidder – but a decision won't be made until 2011-2012.

Radio telescope arrays are not new. Indeed, there are similar arrays all over

SCIENCE SNAPSHOT:

The Big Questions

The SKA will attempt to shed light on the most fundamental – and baffling – questions we have about the universe.

Q: Is Einstein right?

A: Einstein's theory of general relativity is surprisingly robust. The SKA will hunt down extreme astronomical phenomena, such as pulsars and black holes, to put Einstein to the test.

Q: What are magnets?

A: Magnetism is a fundamental part of the universe, yet we still don't really understand how it works, where it comes from, and how it influences the formation of stars and galaxies. The SKA can observe cosmic-sized magnetic fields with greater clarity than any other telescope.

Q: Who turned on the lights?

A: In the beginning, there was a very large bang, then around 500 million years later, the universe was starting to fill with stars and galaxies – but we have no idea what happened in the intervening period. The SKA will look for evidence of the first luminous structures that formed after the Big Bang.



Q: How did the universe evolve?

A: We know very little about dark energy, except that it makes up 70 per cent of the universe and is pushing everything apart. The SKA will be able to see billions of galaxies, determine their relative positions, and discover how the universe came to be.

Q: Is anybody out there?

A: The SKA will be able to peer into other star systems and observe regions where Earth-like planets are likely to form. It will also have the sensitivity to detect radio leakage from other planets.

the world, from the Very Large Array in New Mexico, to the continent-spanning European VLBI Network. So how does the SKA compare? Brian Boyle, CSIRO's SKA director, says the new array will leave all other telescopes in its dust.

"The SKA will be 50 times larger in terms of collecting area, it can take in two to three times as much data, and it can look at 100 times more of the sky simultaneously than other radio telescopes. If you multiply those three things together, you end up with a number that's in the order of 10,000 times the information gathering ability, or discovery potential, of any other previous radio telescope."

COSMIC CONUNDRUMS

This kind of sensitivity, combined with its ability to map large swathes of the sky, will yield important information about many aspects of the universe, from the origins of stars, to fundamental aspects of dark energy and cosmic magnetism. Perhaps its most significant advantage will be its ability to peer into the most ancient parts of the universe – areas which have been previously off limits to astronomers.

"It will allow us to probe the 'dark ages,'" says Watson. "This was a period before the first stars formed, where most of the material in the universe was cold hydrogen and dark matter. The thing about cold hydrogen is that it actually emits radio waves, and so even though we can't probe that region with optical telescopes, it is open to us in the radio region of the spectrum. You can actually look back to a time, by looking into very great distances, 13 billion years ago."

Astronomer Bryan Gaensler, who played a pivotal role in determining the key science projects for the SKA, says the dark ages represents a crucial gap in our understanding of the universe. "We know there was a Big Bang, we know that there were lots of gas and stuff from the Big Bang, but there's no reason why that gas couldn't have stayed smooth and just slowly span outwards forever."

According to Gaensler, such a poor understanding of this vital aspect of the universe is like seeing a picture of a fertilised egg, and then seeing a teenager; and not being shown anything in between

of how the egg became the teenager.

The SKA's wide field of view will also help us understand dark energy. Little is known about dark energy, except that it is accelerating the expansion of the universe. One way to observe its effect is by monitoring as many galaxies as possible – around one billion – which will let us see how the structure of the universe has changed over time. Since dark energy plays an important role in determining this structure, the data collected by the SKA will reveal, for the first time, key aspects of this mysterious force.

BREAKING EINSTEIN

While astronomers will be taking advantage of this new perspective on the universe, there is a far more important question to be answered that may affect the way we perceive science generally. That is, Einstein's theory of relativity.

It's difficult to overstate the impact of Einstein's groundbreaking theory. Like Newton before him, Einstein expanded, corrected and refined prevailing theories about the universe. But unlike Newton, Einstein's explanation is incredibly precise, despite our best attempts to find fault with it.

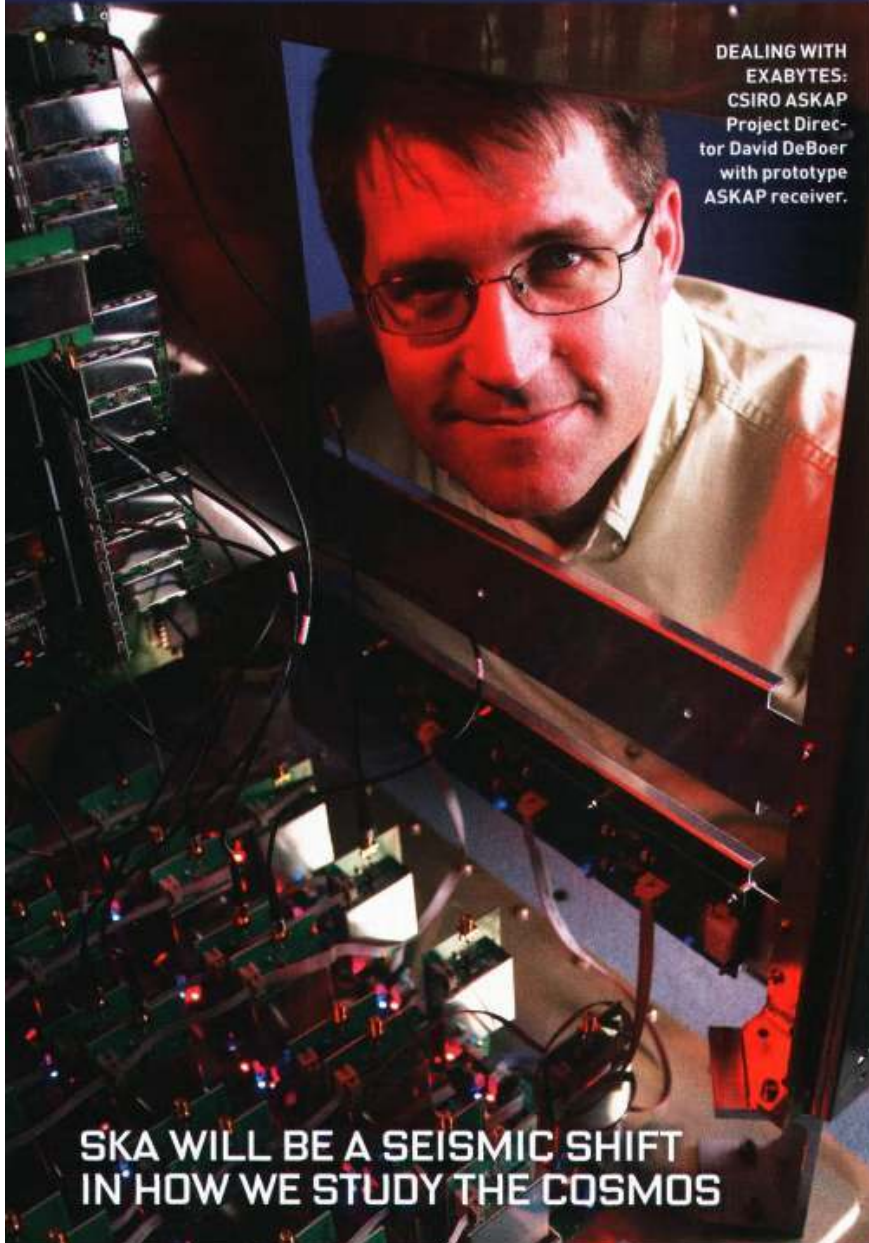
"So far, everything we've thrown at general relativity has passed," says Gaensler. "But it turns out that we haven't really thrown much at it. If general relativity were a brick wall, we've thrown a few tennis balls at it, but we haven't shot it with a cannon."

To really challenge the predictions of general relativity, it needs to be tested under extreme circumstances. One example would be a neutron star orbiting a black hole, where the presence of the black hole would influence the timing of the star's ordinarily precise 'pulsing'. General relativity makes specific predictions as to how the 'ticking' of the pulse would be affected by the black hole, and the SKA will have the capability to locate and observe these pulses. The data will either confirm the predictions of general relativity, or it will tell us that Einstein's theory needs revising.

"These are tests that simply cannot be done on Earth, and so Einstein's theory remains," says Gaensler. "It's like having a bridge that only a puppy has run across,



THE FUTURE OF ASTRONOMY



DEALING WITH EXABYTES: CSIRO ASKAP Project Director David DeBoer with prototype ASKAP receiver.

SKA WILL BE A SEISMIC SHIFT IN HOW WE STUDY THE COSMOS

and then claiming it's safe. It's not until the first fleet of trucks drives across it that you really know."

THE NEW ASTRONOMY

For Gaensler and other scientists around the world, the SKA is not simply a bigger telescope. It's a seismic shift in how we study the cosmos. As the array maps the sky, it will suck down enormous amounts of data, which will be processed, archived and mirrored around the world. So, rather

than observing the sky, astronomers will be probing the archive.

"The datasets in the SKA are going to be insane," says Gaensler. "This is a whole new way of doing astronomy. It's not the same thing piled higher and deeper, we don't even have a way of thinking about or describing or analysing the sorts of datasets we'll be getting."

CSIRO Project Director David DeBoer is the technical arm of the SKA, and it's his job to figure out how to deal with the

immense amount of data the array will collect every day. At the heart of the array will be an 'exaflop' supercomputer that can perform vastly more operations per second than today's fastest supercomputers. In fact, the computer is so advanced that it could not be built today – DeBoer is basing the design on predictions made by Moore's Law, which is a rough benchmark for determining computer power in the future. By 2020, the date when the SKA is due to come online, such a computer will probably exist.

But the biggest challenge involves storing the information, and while the final details haven't been decided, the SKA could be gulping down five exabytes of data every week. "And that's after having huge data compression," says DeBoer. "If you just took the raw data from the antennae, the numbers become even more absurd." Furthermore, even if you can figure out a way to store all that data, the array will be continually surveying the sky, creating ever more data to store.

To solve this problem, DeBoer is working with astronomers and scientists to create special software that plucks the most relevant data from the archive: "You basically have to project your intelligence into the archive and then you'll extract that bit you hope you need. So if you have a team that wants to do a particular survey, [such as] determining the evolution of galaxies or the magnetic fields of galaxies, what they have to do is, as the data streams by them, come up with a way to pull out the scientifically valid data and discard the rest of it."

The final piece of the puzzle is the communications backbone, which will rely on the government's multi-billion dollar National Broadband Network. A priority link will be laid from Geraldton to Perth, but the NBN will be crucial in keeping the communication channels open between all telescopes in the array.

THE CASE FOR AN AUSTRALIAN SKA

After speaking to the Australian astronomers involved with the SKA, you would think the project is destined for our shores, but the proposed sites in South Africa also satisfy the SKA's stringent



SCIENCE SNAPSHOT:

An Outline of Cosmic History

The Big Bang

300 thousand years

The universe becomes neutral and opaque.

500 million years

Galaxies and quasars begin to form. The reionization starts.

Cosmic renaissance. The Dark ages end.

1 Billion years

Reorientation complete. The Universe becomes transparent again.

Galaxies evolve.

9 Billion years

The solar system forms.

13 Billion years

Today

criteria. The question now is: Which site is the most appropriate? According to Brian Boyle, Australia has a very good chance.

"Australia and New Zealand have a very strong scientific and technical case to make. We have an abundance of 'radio quietness' and the population density at the core [of the array] is extremely low. It is slightly larger than the area of the Netherlands, but with a population, in total, of 110 people. Or, as I like to say, three nanopeople per square metre!" In addition, the Australian Communications and Media Authority (ACMA) declared the site a radio-quiet zone, which will limit the amount of interference in the area.

A key part of the Australian bid also involves the Australian SKA Pathfinder (ASKAP). This array, due to be built in 2013, will share many of the characteristics of the larger SKA, including a wide field of view, and demonstrate Australia's technical capability and the suitability of the Western Australian site. With ASKAP on the way, the National Broadband Network in the pipeline, and the federal government's continuing support of Australian astronomy, such as its recent commitment of \$80 million to build the Pawsey High Performance Computing Centre in Perth, it seems Australia's case is looking stronger and stronger.

But it's not just the infrastructure that might tip the scales towards Australia. According to Watson, Australian astronomers are among the best in the field – particularly with regards to radio astronomy – and our can-do attitude is renowned around the world. "We punch far above our weight, in terms of what we achieve with the resources we have, and we have pioneered a number of well-established techniques in astronomy.



RADIO HEADS The 64-metre telescope at the Parkes Observatory, 380km west of Sydney (top). Above: CSIRO SKA Director, Brian Boyle.

People know that Australians can operate any system, no matter what it is. And no matter what nature or circumstances throw at us, we'll get it going and make it work properly."

While we won't know for at least two years where it will be built, the SKA's revolutionary capabilities and the discoveries it is anticipated to make, will ensure that the universe will never look the same again.

	...EQUALS...	...OR
4.7 GIGABYTES	The amount of information stored on a single layer DVD.	The amount of data ASKAP will collect in just under two seconds.
25 GIGABYTES	The capacity of a Blu-ray disc	The amount of data the SKA collects in one millisecond.
92,274,688 GIGABYTES	The storage capacity of the android Data in <i>Star Trek: The Next Generation</i> .	The approximate amount of data stored in the ASKAP archive after two years.
5,368,709,120 GIGABYTES	Around a month's worth of internet traffic.	The amount of information collected by the SKA in a week.