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The Square Kilometre Array (SKA): Scanning the Skies for Life – Where it Began, Where Else it Exists, and What it Signifies

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If you go far enough out
you can see the Universe itself,
all the billion light years summed up time
only as a flash, just as lonely, as distant
as a star on a June night,
if you go far enough out.

And still, my friend, if you go far enough out,
you are only at the beginning
– of yourself. (Jacobsen 1993, 155)

Numerous poets have waxed philosophical about time – that elusive and fragile thread that connects all our lives and the lives of every creature that has walked on this pale blue dot that we call home. Time – there is never enough of it, or sometimes there is too much of it, but no matter how you look at it – it's all about time. And, as most physicists can tell you, it's also about space, because they are eternally connected as Einstein revealed to us in his theory of general relativity (1915). The premise is complex and difficult to grasp for those of us not hard-wired for science. But, popular culture and numerous science-fiction movies featuring space travellers returning home without having experienced the same ravages of age as their earthbound counterparts, subliminally at least, helped us appreciate that there is a connection.

One of the most mysterious and compelling facts I learned when I first delved into amateur astronomy is that the starlight we see in our earthly skies actually left its source hundreds, thousands, or even millions of years in the past. That light we see with our naked eyes has travelled far through time. Stargazing is a lesson in history as well as in science. It is both overwhelming and humbling to consider what we might learn if we had the capacity to look back to the beginnings of our Universe – about the cosmos, the billions of galaxies, the other worlds that spin silently across vast distances, and, more importantly, our place in that Universe. What if we had a telescope large and powerful enough to look back in time and space to the moment right after the Big Bang, when stars and galaxies were just emerging from the legendary "primordial soup" and bringing the first glimmers of light to an evolving Universe? If all goes as planned, we will in fact have such a telescope, and it will experience "first light" or perhaps more accurately, "first signal," as early as 2016. And, when it does, it will bring us to the threshold of not only a brand-new chapter in the understanding of the Universe we live in, but quite possibly significantly closer to the ultimate soul-searching question that has been asked by every human being who has walked the terra firma of this planet – why are we here?

Figure 1 — Dr. Russ Taylor

In 1994, Dr. Russ Taylor, Professor of Physics and Astrophysics at the University of Calgary and Director of the Institute for Space Imaging Science, charted the future course of Canadian radio astronomy leading to our involvement in the Square Kilometre Array (SKA). In 2000, he spearheaded the Memorandum of Understanding to establish the International Square Kilometre Array Steering Committee (ISSC), which included personnel from 11 different countries (subsequently expanded to 20 participating countries through further agreements and structural changes). Canada has been involved from very early on in the SKA, a project billed as the radio telescope for the 21st century, and the instrument of a major revolution in astronomy.

The SKA will push the boundaries of radio astronomy by "marrying" the power and capability of new and exciting developments in radio-frequency technology with advancements in information and communication technologies. By combining leading-edge technologies and harnessing the efforts of teams of professional scientists, engineers, and technicians from various countries, it will turn on one extremely focused "eye on the sky" for the global community. We will be able to look further out into the radio Universe than ever before, with the largest, most sensitive radio telescope in the world. In common with many modern "big science" astronomy projects, the international nature of the SKA symbolizes unity in a common goal to discover our cosmic roots.

The inclusive international flavour of the project cannot be overemphasized; today it is a highly evolved collaborative programme, a trend that is set to continue. Guided by the SKA Science and Engineering Committee (SSEC), the present successor to the ISSC, the project combines the talents and dedication of scientists and researchers from numerous countries including Argentina, Australia, Brazil, Canada, China, France, Germany, India, Italy, the Netherlands, New Zealand, Poland, Portugal, Russia, South Africa, Spain, Sweden, the United Kingdom, and the United States. The international team is supported by a number of working groups that are interested in the full spectrum of issues that the SKA will explore, many of which are described as "key science projects" in the SKA Science Case Book. Nor have the immediate and long-range social impacts of the SKA on the communities in which it may eventually operate been neglected. Some of the initiatives in that regard have been ground breaking in their own right, and could serve as models for other big science projects, particularly those sited in disadvantaged communities.

But before we look at some of the things that the SKA will be able to do, it is important to appreciate how the array actually works, and the science and engineering that make it possible.

In its basics, a radio telescope works much like a classic reflecting telescope. The collector, which typically can be a parabolic dish, functions like a primary mirror, gathering electromagnetic radiation (light waves in the case of the reflector, radio waves in that of the radio telescope). The form of the dish focuses the electromagnetic radiation onto an antenna, the equivalent of the reflector's secondary mirror. The receiver amplifies and converts the radio waves to electrical signals, and can be thought of as somewhat analogous to the reflector's eyepiece and filter. The detector works like the eye or a CCD chip, enabling the electromagnetic radiation to be recorded, and the recorder/analyzer fulfils some of the tasks of the astronomer's brain at the end of the reflector's eyepiece, remembering and analyzing the data.

The promise and possibility of SKA data reshaping our view of the cosmos owes everything to the recent course of radio astronomy. When conjuring up celestial images of distant galaxies and colourful nebulae, the public usually thinks only of optical telescopes, such as the legendary *Hubble Space Telescope (HST)*, but many of the most dramatic discoveries of 20th-century astronomy were won in the realm of the radio region of the electromagnetic spectrum. A striking and well-known example is the Crab Nebula (M1, NGC 1952), a mass of dust and luminous gaseous filaments produced by the supernova of AD 1054, and a favourite of astrophotographers. It is also the site of the neutron star identified as the Crab Pulsar (PSR B0531+21), initially identified through radio observation, and the first such object to be connected with a supernova remnant. Viewing radio frequencies also allows astronomers to penetrate cosmic dust, and peer into areas of the Universe opaque at visible wavelengths and formerly shrouded in mystery – localities such as the centre of our galaxy (Burke & Graham-Smith 2009, 216-220), and those veiled cosmic nurseries where stars and planets are born, such as the iconic "Pillars of Creation" in the Eagle Nebula (M16, NGC 6611; Pound & Kane et al. 2005).

The SKA should prove a very powerful and flexible engine of discovery. It will have a collecting area of approximately one square kilometre (hence the telescope's name), with the SKA central region to contain about 50 percent of the total collecting area. When used in its "aperture synthesis" mode, in which the signals from separate antennae will produce images that have the angular resolution of an instrument the combined size of the entire collection, it will boast a diameter equal to the largest antenna separation – at least 3000 km. The array of antennae, resembling the ubiquitous satellite dishes that are such a familiar sight in our technological society, will be in the thousands. As planned, it will dwarf other yet-to-be-completed projects. The SETI Institute and the UC Berkeley Radio Astronomy Laboratory (RAL)'s Allen Telescope Array, an impressive undertaking in its own right, and an important "stepping stone" and developmental tool towards the SKA, will consist of 350 antennae with a collecting area of 10,000 m^2 upon completion.

The SKA will enjoy a very large field of view (FOV) with a goal at frequencies below 1 GHz of 200 square degrees, and of more than 1 square degree (about 5 full Moons) at higher frequencies. The survey speed of the instrument will be rapid at present-day scale, innovatively effected by the use of Focal Plane Arrays using phased-array technology to provide multiple FOVs. This technology will also make it possible for multiple users to observe different pieces of the sky simultaneously.

The SKA has the potential to look back in time to those events that occurred shortly (relatively speaking) after the Big Bang, when the Universe contained no light save for the faint glow left over from the Big Bang – aptly referred to as the Dark Ages by Big Bang cosmologists.

The SKA Science Case information booklet describes the project as a "discovery machine" but it is also a "questioning machine." And, the questions that it will ask are not small and they are not easy: What happened after the Big Bang and before the first stars and galaxies formed? Which came first, stars or galaxies? What is the mysterious dark energy? How are galaxies born and how do they evolve? In particular, the SKA will measure the amount of hydrogen, nature's most abundant and fundamental element, present in various galaxies across time, and this will help scientists determine the geometry of the Universe. The SKA Science Case tells us that this in turn will test "whether dark energy is a vacuum energy or something more exotic like evidence of a genuinely new physics of extra dimensions." For most of us, these are very powerful concepts, usually confined to the realm of science-fiction movies and books. Dark energy and alternate dimensions are heady abstractions; although we might be able to imagine the existence of another dimension, are we able to absorb the ramifications of such a discovery in terms of our own existence? The SKA will take us into new frontiers in more ways than just the hard science.

The SKA may even possibly address fundamental epistemological questions about how we do science, questions such as: Can we predict everything in the Universe on the basis of what we already know now? The SKA Science Case reminds us that, considering that the SKA's most productive years will be in the period from 2020 to 2050 and beyond, its primary users have yet to be born. And, the questions, aspirations, and searches that will propel their research are not yet known and may well be inspired by some of the early data that SKA reveals in the years from 2016 to 2020.

In the course of the SKA's ongoing scientific programme, its innovations in astronomy may potentially trigger responses in areas such as philosophy, spirituality, and religion. Perhaps these may even touch on questions such as: Who are we, how did we get here, and what is our purpose?

As I wrestled with the possible broader effects of the SKA's scientific programme, I was fortunate to be able to speak with Prof. Russ Taylor and gain his perspective on the intersections of science and philosophy.

"By charting a complete history of time, we will hope to understand whether the rise of life was encoded in the event that created the Universe," he patiently explained, "Is the world as we know it logically necessary as the result of the initial conditions of the Big Bang or was it an accident? In other words, was life necessary?" Or, as a philosopher pondering the same question from a more metaphysical perspective might ask – not so much as to whether life was necessary, but if it wasn't "accidental" in scientific terms, does if have a larger purpose or, indeed, does it have any purpose at all? Or, are we merely a random event?

Such metaphysical questions arising out of an astronomical research programme may potentially have a major impact on countless concepts that give rise to many of the world's major religions and philosophies.

Prof. Taylor is well aware of the depth of the questions that the SKA will not only pose, but seek to answer. "The questions we are asking border on philosophical and religious questions that are fundamental to understanding our place in the Universe. In probing to the far edges of the Universe, we are really asking questions about ourselves."

The SKA could also provide us with long-sought-after answers about the existence of other intelligent life. The sensitivity of the array is such that it could detect signals as weak as the "radiation leakage" that seeps from our planet daily as the result of the use of such everyday devices as cell phones, TV transmitters, and radar. The discovery of similar signals emanating from a planet orbiting another star would be what the SKA project describes as "a profound moment for humanity." The presence of such a signal, could, for the first time in our human history, lead us to reasonably conclude that we are not alone.

In the last 15 years, over 500 extrasolar planets have been detected. What if an intelligent, purposeful signal is detected by the SKA emanating from an Earth analogue? Such a discovery could both comfort and terrify us. For most of us, I would speculate, it would be something in between, but there is probably hardly a soul who would be unaffected. As we grow closer to the launch of what promises to be one of the most exciting and dramatic scientific undertakings of the 21st century, there is indeed much to ponder.

The SKA will bring together some of the finest scientific minds of our planet, and we can be proud that Canada and the University of Calgary are taking a lead role. It is expected to be complete and fully functional in 2020, although Prof. Taylor tells me that Phase One will be operational as early as 2016. The final site for the location of the array will be selected by 2011, and the two potential host countries for the project, South Africa and Australia, are currently developing their sites and building prototypes of the telescopes.

Five years, relative to the span of human history, is seemingly infinitesimal. But, in the time from now until 2016, the SKA could be producing its "first science." Those discoveries have the potential to be truly transformational in ways that we would expect and in some that we can hardly imagine.

The science that the SKA reveals will also bring us on a human journey that could challenge everything we have come to believe about ourselves, and the nature of our existence. To paraphrase the Norwegian poet Rolf Jacobsen: "If we go out far enough, we are only at the beginning – of ourselves." With the SKA, we will become time travellers, and like all intrepid pioneers, we must be prepared for what we find. In looking back and reaching an understanding of how our Universe and our planet were born, we may also come to know why. That revelation could potentially shake the foundations of many of our core belief systems. Are we ready?

Maureen Arges Nadin has been exploring uncharted territory in the world of freelance writing since 2005, after a successful 28-year career in the Public Service. She has been fascinated by the night skies since she was a small child, and was first struck by the wonder of space travel when Sputnik was launched. She is long-time member of the Thunder Bay Centre.

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