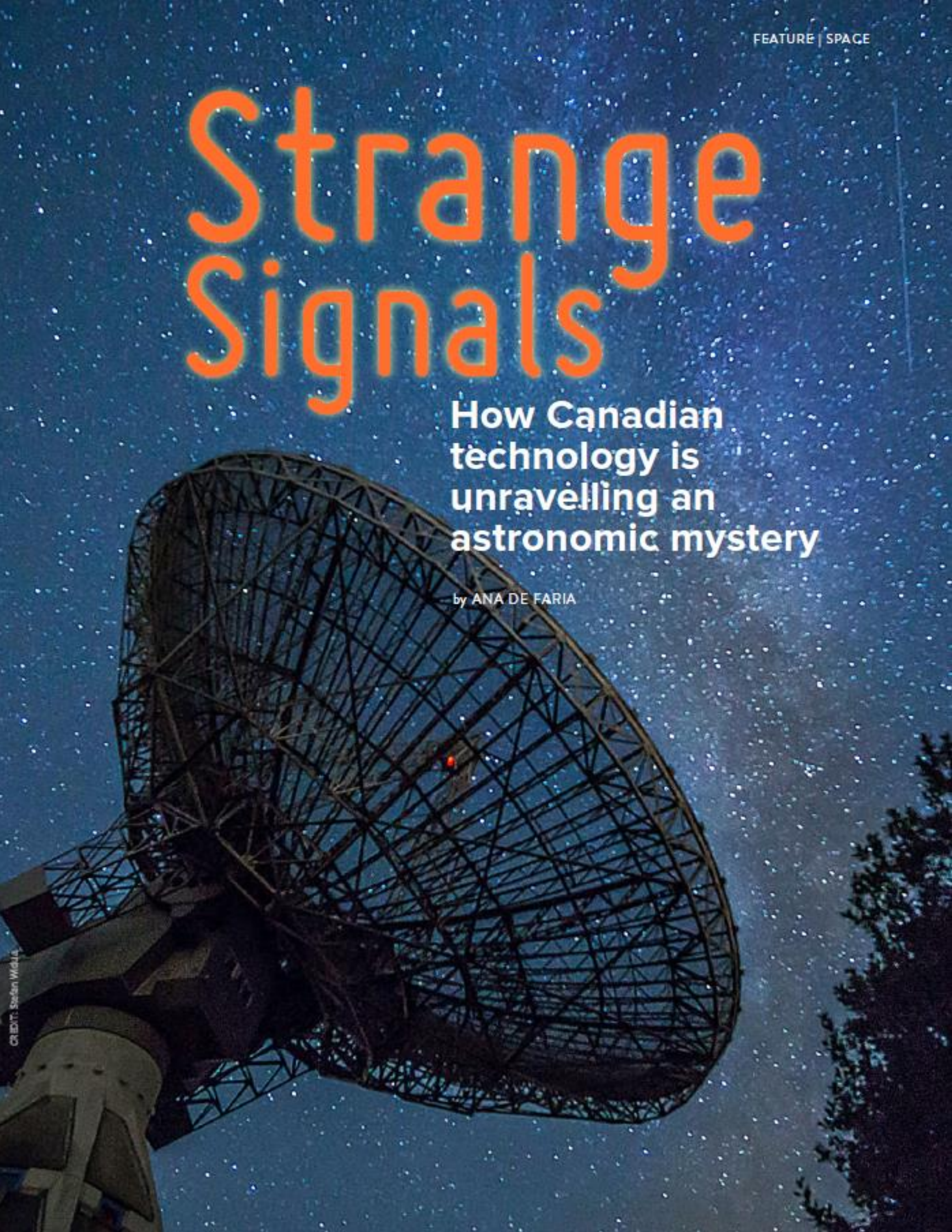
Strange Signals

How Canadian technology is unravelling an astronomic mystery

by ANA DE FARIA



CREDIT: Stefan Widua

IN 2007, AUSTRALIAN SCIENTISTS were looking through archival data from 2001 taken by the Parkes Radio Telescope in New South Wales, and found signals different from anything ever detected before. These bursts of radio light, later known as Fast Radio Bursts (FRBs), remain a mystery. They carry huge amounts of energy, last only a few milliseconds and seem to come from billions of light-years away. In the last few years, Canadian technology has been investigating these signals and may have finally found an explanation for this phenomenon.

A BRILLIANT FLASH, THEN NOTHING

For years, it was not clear if FRBs even existed. In the few years following its initial discovery, the Parkes Telescope detected a handful of potential FRBs that were later found to be false alarms. It turned out that if you open a microwave too early, it lets out a burst of radio light not unlike FRBs. It was not until 2013 when the Parkes Telescope found four more FRBs in their archival data that the skepticism lessened.

In 2014, two other telescopes detected similar signals, each in their own archives. These were the Arecibo Telescope in Puerto Rico and the Green Bank Telescope in West Virginia. These discoveries finally convinced astronomers that FRBs are real.

Many theories arose to explain the origin of FRBs, ranging from well-known astronomical phenomena to an entirely new physics. The handful of examples were not enough to go on. Astronomers needed to find more of these strange signals.

Interestingly, thousands of FRBs occur all over the sky every day. So why have we detected so few? The reason is simple. Radio telescopes sensitive enough to catch an FRB can only see a small region of the sky at a time. Smaller telescopes can see larger areas of the sky, but are not sensitive enough to catch an FRB. What scientists needed was a very sensitive telescope that could look in a lot of different directions at once. That's how Professor Keith Vanderlinde and the Canadian Hydrogen Intensity Mapping Experiment (CHIME) entered the scene.

FROM MAPPING THE UNIVERSE TO REVEALING MYSTERIOUS RADIO SIGNALS

The CHIME project was developed to study the universe using radio frequencies.

Prof. Vanderlinde is an experimental cosmologist and long-wavelength instrumentalist at the University of Toronto and one of the coordinators of CHIME. He spent the first decade of his career studying the Cosmic Microwave Background (CMB), the first light emitted when the universe was born. Scientists can detect CMB using microwave light and capture it in pictures that map out the universe. "The whole sky glows all the time and it is just filled with microwave light leftover from when the universe was really just a baby," Dr. Vanderlinde elaborates.

Looking at neutral hydrogen, which can be mapped by collecting the radio waves it emits (a glow with a wavelength of 21cm), is one strategy employed to better understand the universe. This would take a long time using traditional radio telescopes—decades, if not centuries. But, a new breed of telescope can be built using off-the-shelf technology that can collect the light from neutral hydrogen glow (HI) in a matter of years. The result will provide a more detailed picture of the early universe, in particular, the time during which the mysterious 'dark energy' arose and sped up the universe's expansion.

Professor Vanderlinde and his team built a telescope using parts commonly found in cell phones and video game consoles. The CHIME telescope works quickly by looking in a lot of different directions at once. It achieves both sensitivity and a large field of view. Serendipitously, this is also the perfect telescope to search for FRBs.

THE END OF A MYSTERY OR THE BEGINNING OF A NEW ONE?

"[The astronomers working on FRBs] came along and talked to us, [and we said] yeah we could probably repurpose CHIME to do this—we could build a CHIME/FRB," recalls Prof. Vanderlinde. "And it turns out, you don't even need to repurpose it; you can run both of these studies completely in parallel. You upgrade the computer, you rewrite the software and suddenly this is

CHIME is a collaboration between the University of Toronto, University of British Columbia, McGill University, and Canada's Dominion Radio Astrophysical Observatory. Originally conceived to map the most abundant element in the universe, hydrogen, this unusual telescope has no moving parts and is composed of four large cylinders, 100 meters long and 20 meters wide each, arranged north-south, with a thousand detectors spread across them. CREDIT: Wikimedia Commons searching for FRBs. We did that and at the instant it came on, we started seeing them." In 2019, CHIME/FRB was featured on the cover of *Nature* with its first series of results.

CHIME/FRB has since detected over a thousand FRBs. We now know that while most FRBs are one-offs, some of them actually repeat, turning on and turning off with some periodicity. "This is a relatively new discovery and discovered by Canadian technology as well," says Nicole Mortillaro, the Senior Science Reporter for CBC News who reported one of the first stories about CHIME/FRB.

We still don't know how to classify one-offs and repeaters. Qualitatively they are slightly different, but it is unclear if there is one class of objects or multiple. As we investigate further and collect more samples, we may be able to answer this question. That's why an experiment like CHIME, which detects hundreds of FRBs a year, stands in a great position in the field.

In 2020, CHIME/FRB detected an incredibly bright burst that was traced to a magnetar—a super, highly magnetized neutron star—only 30,000 light-years away in our galaxy. "When things are near, you can see fainter bursts," explains Prof. Vanderlinde. "So, it makes it a little bit easier [to study]." A magnetar has a magnetic field a million billion times stronger than Earth's, strong enough to pull atoms apart. Studying how FRBs are produced in this environment and how they travel through it can additionally help us study the wider universe and learn about dark matter and dark energy.

"It is quite an achievement though, and it's definitely something I think that we can be very proud of in Canada," says Mortillaro. "When I first did my interview with one of the CHIME scientists, [they said] we went from detecting a few [FRBs] to the possibility of detecting hundreds in a week. That's just amazing." ●

CREDIT: M. Kornmesser/ESO

NEUTRAL HYDROGEN GLOW

Hydrogen is the most abundant element in the universe—three-quarters of all matter is hydrogen. Despite this, mapping the neutral hydrogen glow (H1) across large spans of the universe is a challenge. There are three basic problems:

- All hydrogen was neutral at the start of the universe, but the birth of galaxies resulted in processes that lead to hydrogen being ionized. For example, as early stars formed, they turned hydrogen into glowing plasma. Glowing nebulas like the Orion Nebula are made of ionized hydrogen. As such, the vast majority of the universe's hydrogen isn't neutral, and doesn't emit this radio glow.
- The glow itself is produced by a change between two states in the atom which happens rarely. It takes on average about 10 million years for a single hydrogen atom to emit a single photon of 21cm radio light. It is so rare, in fact, that it has been posited that extraterrestrials would use the 21cm frequency to communicate with us.
- This very rare radio glow is produced at very distant regions in the universe.

This is why finding H1 using traditional radio telescopes would take decades or centuries.

THE PHYSICS OF LIGHT

Let's take a few steps back and talk about light. Everybody knows the colours of the rainbow (red, orange, yellow, green, blue, indigo and violet) but that's not all of it. There are many more "colours" of light out there, known as wavelengths or light bands. If we zoom out of the visual "rainbow" and view the entire light spectrum, we see (from one end to the other) gamma rays, X-rays, UV-light, visible light (the rainbow we can see), infrared, microwave and radio waves. Gamma rays are shorter, faster, more energetic and more dangerous. Radio waves, on the other hand, are longer, slower, less energetic and less dangerous. But all of these wavelengths are the same phenomena: they're all just light. The only thing that makes visible light special is that our eyes can see it. FRBs belong to the longer end of the light spectrum—radio waves—and can be detected by radio telescopes, like CHIME, Arecibo, Green Bank and Parkes.

ZOONIVERSE

Interested in becoming an FRB hunter? CHIME/FRB can be found in Zooniverse, a citizen science web portal hosted by the Citizen Alliance. Due to the incredible amount of data that CHIME/FRB generates (about 1 Terabyte per second), it is hard for software to differentiate real FRBs from electronic noise. A human, however, can do this easily. You can help by visiting CHIME Zooniverse. No sign up is needed, and the platform will give you all the training you'll need to start looking at the data and classifying FRBs. According to Prof. Vanderlinde, the FRB realm is an exciting field to be in.

Click here to watch the full event.