First Light for the CHIME telescope

Canadian Hydrogen Intensity Mapping Experiment (CHIME) is a new radio interferometer located at the Dominion Radio Astrophysical Observatory (DRAO) in British Columbia. At the McGilll Space Institute, ***Prof. Matt Dobbs****,* ***Prof. David Hanna*** *and* ***Prof. Vicky Kaspi*** *are involved with CHIME along with nearly two dozen McGill students, postdoctoral fellows and technicians*

Future of CHIME

CHIME is now in its commissioning phase, in preparation for science operations. This new telescope will bring Canada to the forefront of an emerging important and technically challenging domain of radio astronomy. More information on CHIME can be found at chime-experiment.ca.

CHIME, the $16M new Canadian radio telescope, saw its "First Light" on September 7th and was celebrated at a ceremony in Penticton, BC involving Federal Minister of Science, Kirsty Duncan.

The telescope is designed to simultaneously make unprecedented maps of the distant universe to understand the nature of dark energy, study pulsars, and help determine the origin of the mysterious phenomenon of Fast Radio Bursts.

Now that all the major components are in place, the first data from the instrument is starting to be collected. "After years of work it's fantastic to finally see the graphs showing real sky data coming through the system on all channels," said Nolan Denman, a graduate student at the University of Toronto, who produced the first light plots after an overnight session collecting data during the transit of Cygnus A (a nearby galaxy that is bright at radio wavelengths and is a useful source for calibrating the instrument).

Science

CHIME will probe the fundamental nature of dark energy, the mysterious agent that causes the accelerated expansion of the universe, by producing a three-dimensional map of the 21-cm emission from neutral hydrogen that covers the entire northern sky and spans redshifts 0.8 to 2.5. This will enable a measurement of Baryon Acoustic Oscillations (BAO) in the large scale distribution of neutral hydrogen — a relic that originates from sound waves propagating in the early universe. The size of the BAO feature will be used as a standard ruler to measure the expansion history of the universe during the epoch when dark energy generated the transition from decelerated to accelerated expansion.

Two further key science projects are currently under commissioning and will soon be conducted simultaneously alongside the cosmology experiment. These include a blind survey for Fast Radio Bursts (FRBs), energetic single pulses of radio emission arriving in

« CHIME at night: The telescope consists of four parabolic cylinders that are 20 m wide and 100 m long with a focal length of 5 m. It has no moving parts, instead relying on the earth's rotation to move the sky across its field of view.

random directions from unknown sources well beyond our galaxy. So far progress in resolving the mystery of their origin has been limited by the low survey efficiency of traditional single dish telescopes. With its huge field of view and broad frequency coverage, CHIME is a nearly ideal instrument for finding and studying many of these bursts. "It has taken almost 10 years to observe 25 FRBs with different telescopes" noted McGill postdoc Emmanuel Fonseca, adding, "CHIME is expected to detect 25 FRBs within one week of operation." Pinning down their rate will be crucial for determining the origin of FRBs.

The other project that CHIME will carry out is pulsar timing. CHIME will monitor the pulses from all known pulsars in the Northern hemisphere visible from Penticton, every day. Among other things, this information will aid in the search for gravitational waves — traveling ripples in space-time — passing through our galaxy.

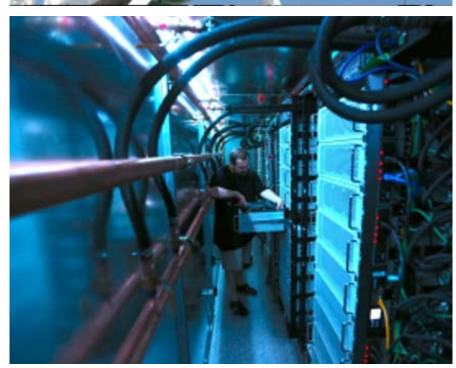
Hardware

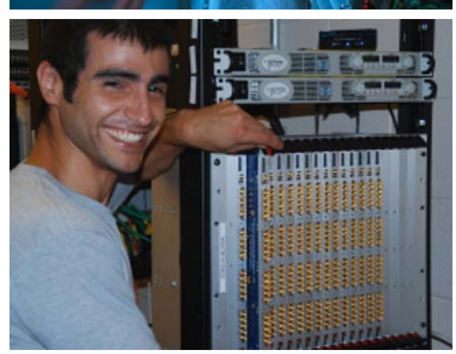
CHIME surveys the northern half of the sky every day as the earth rotates. It is composed of four cylindrical reflecting surfaces that resemble snowboard half-pipes and have a total collecting area equivalent to five hockey rinks (8,000 m^2). It records the information from all the radio waves that hit its surface with over a thousand antennas, made out of conventional low loss circuit boards that can be mass produced economically.

The CHIME correlator converts the massive amount of information that is contained in the radio waves incident on the cylinders into an image of the overhead sky. Measured in number of analog inputs (N=2048) squared times bandwidth (400 MHz), the CHIME correlator is the largest radio correlator in the world — and it was built for a comparatively low price. The correlator employs 128 field programmable gate arrays (FPGAs) to digitize the analog radio signals collected by the antennas and channelize their full bandwidth into 1024 narrow frequency bins. The FPGAs are interconnected through custom, full-mesh backplanes that enable a massive reorganization of 6.6 Terabit/second of data into the format required to compute the N^2 correlation matrix of the signals measured by the antennas. The data is then transmitted over more than a thousand fiber optic cables to a supercomputer.

Using the data from the FPGAs, the CHIME supercomputer creates detailed sky maps and performs real-time beamforming which is used for the FRB and pulsar applications. This requires a huge amount of computing power, which was made possible thanks to the existence of low cost Graphics Processing Units (GPUs) from AMD, which were developed primarily for computer games, but are increasingly leveraged by scientists to perform complex calculations. In total CHIME has 1024 high end GPUs, spread out over 256 servers. Together they are able to perform over 7 quadrillion (a million billion) operations per second.

Undergraduate and graduate students played a key role in the assembly, testing, and on-site installation of the instrument. "My favourite part of working on CHIME has been interacting with all the wonderful people involved in this project. The team's enthusiasm and devotion is contagious" said Emilie Storer, an undergraduate student at McGill who helped test the FPGA motherboards.





» **Top:** *Minister of Science, Kirsty Duncan and Prof. Vicky Kaspi walk under the telescope at the CHIME first light ceremony.*

» **Below:** *Postdoc Cherry Ng connecting some of the 2048 50m-long coaxial cables; Postdoc Emmanuel Fonseca and summer intern Tristan Simmons raising feeds onto the focal line; Graduate student Nolan Denman assembling GPUs in the X-engine; Graduate student Juan Mena Parra installing FPGA motherboards.*