PUBLISHED: 2 FEBRUARY 2017 | VOLUME: 1 | ARTICLE NUMBER: 0037

Unveiling the radio cosmos

Using a radio telescope with no moving parts, the dark energy speeding up the expansion of the Universe can be probed in unprecedented detail, says **Keith Vanderlinde**, on behalf of the CHIME collaboration.

The Canadian Hydrogen Intensity Mapping Experiment (CHIME) is a programme to study dark energy, the invisible 'stuff' responsible for the accelerating expansion of the Universe. The experiment will measure the relic of baryon acoustic oscillations (BAO), spherical shells of matter overdensity in which galaxies and gas are more likely to be found today. The radius of these shells was established by conditions in the early Universe (up to ~400,000 years after the Big Bang) and remains constant in co-moving coordinates afterwards. This characteristic distance scale has evolved solely due to the expansion of the Universe, and so provides a standard ruler with which to measure the expansion rate.

CHIME will map the 21 cm emission of neutral hydrogen over a vast volume of the Universe — half the sky and spanning 4 billion years of cosmic history: the largest-volume survey ever undertaken. Crucially, it encompasses the period when dark energy first became a significant factor. Measurements of the expansion rate throughout this critical epoch will help constrain the dark energy equation of state.

CHIME is a radio interferometer, located at Canada's National Research Council's Dominion Radio Astrophysical Observatory, and sensitive to radio light from 400 to 800 MHz, corresponding to a redshift of 2.5–0.8 for 21 cm radiation. It is composed of four parabolic cylinder reflectors, each 100-m long and 20-m wide and oriented to a north–south axis (pictured here in an image taken from the northwest corner, with the 26-m Galt Telescope visible in the far left). Their focal lines are each populated by 256 dual-polarization radio feeds, whose primary beams resemble thin cigar-shaped stripes ~100° long north–south by ~2° wide east–west.

Analogue signal chains composed of low-noise amplifiers and anti-aliasing filters carry signals to a purpose-built processing back-end. There, they are sampled, channelized and correlated in the world's largest FX correlator, providing the spectral and spatial resolution needed to resolve the BAO. CHIME has no moving parts and scans half the sky every day as the Earth rotates. Instrumentation of the telescope is nearing completion and commissioning observations are expected to begin by spring 2017.

CHIME's tremendous survey speed makes it well suited to a number of science objectives beyond the neutral hydrogen measurement. The instrument will produce detailed maps of the polarization and intensity of galactic emissions over the survey field with 0.5 MHz spectral resolution. CHIME will act as a scientific and technical pathfinder for the Square Kilometre Array, pioneering the measurement of very low surface brightness phenomena and developing key correlator hardware.

A pair of additional back-end instruments — CHIME/Pulsar and CHIME/FRB — will reprocess the CHIME data stream to probe the transient radio sky in unprecedented detail. CHIME/Pulsar provides a specialized system able to study up to ten transiting sources at any given moment, providing daily measurements on hundreds of northern hemisphere pulsars. CHIME/FRB is a significantly larger expansion, enabling a continuous 24/7 search for highly dispersed transients within the thousand formed beams tiling the instrument's primary field of view. Fast radio bursts are mysterious, unpredictable, millisecond-long bursts of radio energy of seemingly extragalactic origin, showing enormous chromatic dispersion. With less than two dozen events in the literature, CHIME/FRB stands to revolutionize the field, with forecasts ranging from one to dozens of detections daily.

The CHIME Pathfinder is a smaller-scale prototype of full CHIME, which has been in operation for two years, informing the design and serving as a testbed for hardware and analysis techniques. The Pathfinder is composed of two cylinders, each 37-m long by 20-m wide, whose focal lines are similarly populated and whose observing band matches that of full CHIME.

CHIME is a collaboration between the University of British Columbia, McGill University, the University of Toronto and the Dominion Radio Astrophysical Observatory. CHIME/FRB and CHIME/Pulsar further include the National Radio Astronomy Observatory and the Perimeter Institute as collaborating institutions.

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