National Centre for Radio Astrophysics (NCRA-TIFR), Pune

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CHIME telescope detects more than 500 mysterious fast radio bursts in its first year of operation

Observations quadruple the number of known radio bursts and reveal two types: one-offs and repeaters.

[Written by Jennifer Chu, MIT News Office and the TIFR/NCRA press team]

Scientists with the Canadian Hydrogen Intensity Mapping Experiment (CHIME) Collaboration, including researchers at the Tata Institute for Fundamental Research (TIFR) and the National Centre for Radio Astrophysics (NCRA), have assembled the largest collection of fast radio bursts (FRBs) in the telescope's first FRB catalog, which they will present this week at the American Astronomical Society Meeting.

To catch sight of an FRB is to be extremely lucky in where and when you point your radio dish. Fast radio bursts are oddly bright flashes of light, registering in the radio band of the electromagnetic spectrum, that blaze for a few milliseconds before vanishing without a trace.

These brief and mysterious beacons have been spotted in various and distant parts of the universe, as well as in our own galaxy. Their origins are unknown, and their appearance is unpredictable. Since the first was discovered in 2007, radio astronomers have only caught sight of around 140 bursts in their scopes.

Now, the CHIME project, a large stationary radio telescope in British Columbia has nearly quadrupled the number of fast radio bursts discovered to date. The telescope has detected 535 new fast radio bursts during its first year of operation, between 2018 and 2019.

"Before CHIME came along, different telescopes had observed a handful of FRBs each, but each with their own selection criteria and software." says CHIME/FRB member Shriharsh Tendulkar, now a faculty member at the TIFR and NCRA. "By observing a large swath of the sky 24/7, we were able to detect FRBs at an unprecedented rate and gather the first large sample of FRBs with a single instrument and a single, well-understood selection criteria. This allows us to get a far better understanding of the properties of the FRBs as a population."

The new catalog significantly expands the current library of known FRBs, and is already yielding clues as to their properties. For instance, the newly discovered bursts appear to fall in two distinct classes: those that repeat, and those that don't. Scientists identified 18 FRB sources that burst repeatedly, while the rest appear to be one-offs.

The repeaters also look different, with each burst lasting slightly longer and emitting more focused radio frequencies than bursts from single, non-repeating FRBs. "We find that repeaters emit bursts of longer duration with the radiation being detected in a narrower range of frequencies compared to the one-off FRBs. These differences strongly suggest that emission from repeaters and non-repeaters is generated either by different physical mechanisms or in different astrophysical environments." says Pragya Chawla, a PhD candidate at McGill University, and a member of the CHIME team.

With more observations, astronomers hope soon to pin down the extreme origins of these curiously bright signals.

Seeing flashes

CHIME comprises four massive cylindrical radio antennas, roughly the size and shape of snowboarding half-pipes, located at the Dominion Radio Astrophysical Observatory, operated by the National Research Council of Canada in British Columbia, Canada. CHIME is a stationary array, with no moving parts. The telescope receives radio signals each day from half of the sky as the Earth rotates.

While most radio astronomy is done by swiveling a large dish to focus light from different parts of the sky, CHIME stares, motionless, at the sky, and focuses incoming signals using a correlator — a powerful digital signal processor that can work through huge amounts of data, at a rate of about 7 terabits per second, equivalent to a few percent of the world's internet traffic.

"Digital signal processing is what makes CHIME able to reconstruct and 'look' in thousands of directions simultaneously," says Kiyoshi Masui, assistant professor of physics at MIT, who will lead the group's conference presentation. "That's what helps us detect FRBs a thousand times more often than a traditional telescope."

Over the first year of operation, CHIME detected 535 new fast radio bursts. When the scientists mapped their locations, they found the bursts were evenly distributed in space, seeming to arise from any and all parts of the sky. From the FRBs that CHIME was able to detect, the scientists calculated that bright fast radio bursts occur at a rate of about 800 per day across the entire sky — the most precise estimate of FRBs overall rate to date.

While most FRBs are in far away galaxies, CHIME also detected many FRBs, including repeaters that are located in nearby galaxies, almost our astronomical backyard. "Though we expect to find more distant FRBs than nearby ones simply because of the size of the Universe to which CHIME is sensitive to detect FRBs, CHIME monitors more than half of the celestial sphere with high sensitivity every day, which increases its chance of detecting nearby FRBs considerably. Therefore, it's no surprise that CHIME is frequently referred to as an FRB detection machine!" Says Mohit Bhardwaj, also a PhD candidate at McGill University.

Mapping the universe

As radio waves travel across space, any interstellar gas, or plasma, along the way can distort or disperse the wave's properties and trajectory. The degree to which a radio wave is dispersed can give clues to how much gas it passed through, and possibly how much distance it has traveled from its source.

For each of the 535 FRBs that CHIME detected, Masui and his colleagues measured its dispersion, and found that most bursts likely originated from far-off sources within distant galaxies. The fact that the bursts were bright enough to be detected by CHIME suggests that they must have been produced by extremely energetic sources. As the telescope detects more FRBs, scientists hope to pin down exactly what kind of exotic phenomena could generate such ultrabright, ultrafast signals.

Scientists also plan to use the bursts, and their dispersion estimates, to map the distribution of gas throughout the universe.

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