Fast radio bursts used as 'searchlights' to detect gas in Milky Way

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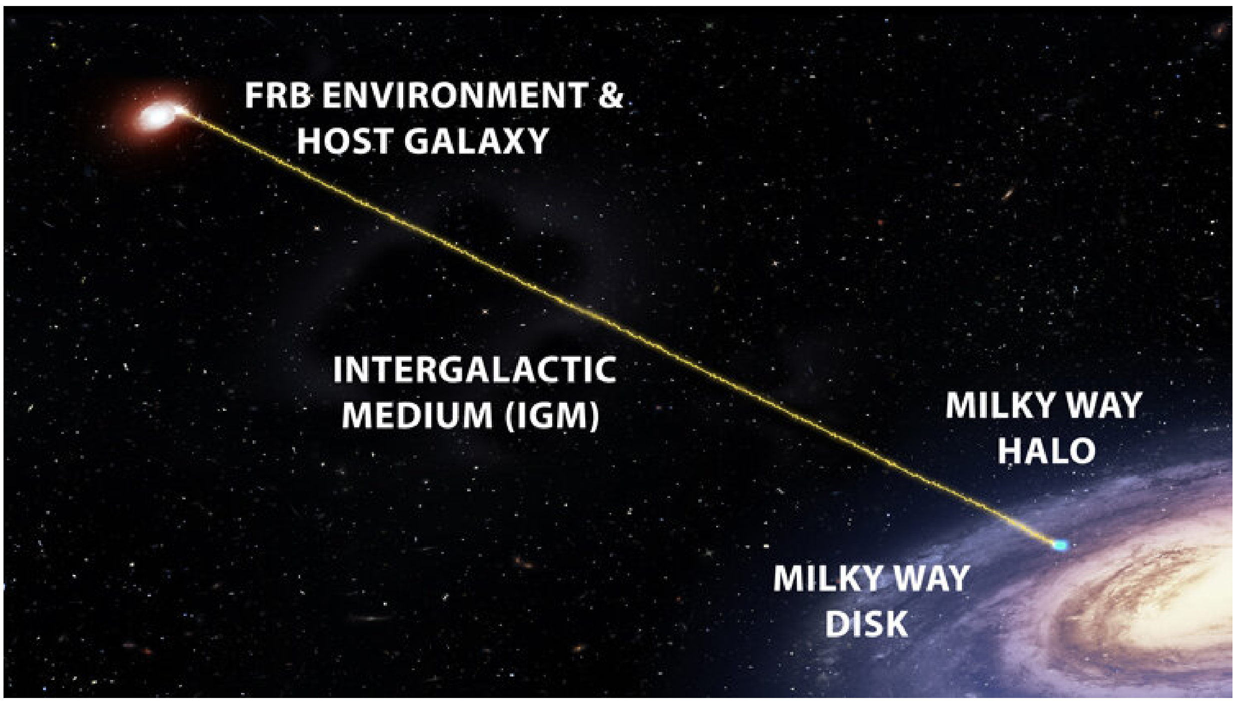

An illustration of a radio signal from a fast radio burst as it moves toward telescopes on Earth. Credit: J. Josephides/Swinburne University of Technology, with minor edits from the Dunlap Institute

University of Toronto researcher Amanda Cook has found a way to use bright signals coming from across the universe to weigh the atmosphere of the Milky Way galaxy.

The radio signals she used come from the astronomical phenomenon known as fast radio bursts (FRBs)—enigmatic celestial objects that generate brief flashes of radio waves and are considered one of the biggest mysteries in astronomy.

Since an FRB simultaneously generates both high frequency radio waves (the equivalent of blue light) and low frequency radio waves (the equivalent of redlight), the different colors of radio waves might be expected to arrive at a telescope at the same time. But that's not what happens. As an FRB passes through gas, it slows down—more so for the high frequencies than the low frequencies. The result is a delay between the different frequencies or colors reaching our telescope, effectively smearing the radio burst's signal out in time.

Astronomers like Cook call this smearing "dispersion" and are able to use it as a tool to detect otherwise invisible gas throughout the cosmos.

"Using smearing to study the universe is like using your home heating bill to work out what the weather must have been like over the winter," says Cook, who is a Ph.D. candidate in the David A. Dunlap department of astronomy and astrophysics, and the Dunlap Institute for Astronomy & Astrophysics, in the Faculty of Arts & Science.

"In the same way that your heating bill tells you whether it was a harsh winter or a mild winter—but not what the temperature was like on any individual date—the smearing that we see allows us to infer the total amount of material that the FRB signal has encountered on its journey from the FRB to Earth. It just can't tell us how that material was distributed along the way."

"The key thing is that regardless of how gas in front of the FRB is distributed, an FRB signal that is smeared more by the time it reaches our telescopes must be produced by an FRB that is farther away in the same way that an expensive heating bill must have meant a cold winter overall," she continues.

In this case, Cook used the dispersion method to measure how much gas is present in the Milky Way's halo—an "atmosphere" of the Milky Way that extends outwards by around a half a million light-years in all directions.

Using FRB signals collected by the Canadian Hydrogen Intensity Mapping Experiment (CHIME) radio telescope, Cook and her team discovered that the Milky Way's halo contains much less gas than previous models had predicted. The results were published in the *Astrophysical Journal* in a study titled "An FRB Sent Me a DM."

Though there had been earlier studies applying related techniques, this is the first time that the halo's gas has been measured using a large uniform sample of FRBs—thanks to the CHIME telescope.

The team used FRB signals at different distances from Earth to get the result. Cook likens this approach to trying to work out the average driving distance from different Canadian border crossings to Toronto by having friends from different American states drive to Toronto, telling you only the total distance they drove. The information from your Texan friend is not going to be particularly useful, but the experience from your Michigan and New York friends may be far more insightful. And if you have friends that live right on the border, in Buffalo or Detroit, then their answers will pretty much give you the information you need.

Cook and her supervisor, Professor Bryan Gaensler, have been working on this research since she was a first-year graduate student. "It ended up being a lot more difficult than we thought," Cook says.

It was difficult enough that she, Gaensler and their colleagues actually stepped outside of conventional astronomical models. They turned to researchers in an entirely different field—statistics—and asked those colleagues for a new set of methods to apply to their approach.

"This is an exciting new way of studying our Milky Way," says Gaensler, who is also an author on the publication. "We're still trying to figure out what fast radio bursts actually are, but in the meantime we can use them as searchlights to study things much closer to home."

Cook and Gaensler note that FRB signals could be used to study the structure of everything that the FRB signal passes through on its long journey, including the material between galaxies, the halos of other galaxies and the gas inside of galaxies.

Meanwhile, many more FRB discoveries are anticipated. With even more data, Cook and her team hope to create a 3D map of the Milky Way halo. "Each FRB gives us a measurement of the Milky Way halo in one direction, so as we continue to collect them, we can build up a detailed picture," Cook says.

Beyond that, she notes that these clues contribute to our understanding of the early universe.

"Improving our knowledge of the Milky Way halo helps us learn about the formation of our galaxy as a whole."

More information: Amanda M. Cook et al, An FRB Sent Me a DM: Constraining the Electron Column of the Milky Way Halo with Fast Radio Burst Dispersion Measures from CHIME/FRB, *The Astrophysical Journal* (2023). DOI: 10.3847/1538-4357/acbbd0

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