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Hardware Design and Array Layout for CHORD: the Canadian Hydrogen Observatory and Radio-transient Detector

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The Canadian Hydrogen Observatory and Radio-transient Detector (CHORD), an interferometric radio telescope developed by a collaboration of Canadian institutions, is in the final stages of prototyping. It will consist in a main core array of 512 close-packed 6 m composite dishes, arranged in a highly redundant layout, along with two 64-dish "outrigger" stations for very-long-baseline interferometry. The dishes, boasting a sub-millimeter surface precision, will be equipped with custom hardware that includes ultra wideband feeds covering the 300–1500 MHz range, and amplifiers reaching noise levels below 15 K.

CHORD builds on the successes of the Canadian Hydrogen Intensity Mapping Experiment (CHIME), sharing its drift scan approach, GPU-based correlator backend, and main science goals, with improved capabilities. It is set to map the integrated emission of neutral hydrogen from low redshift galaxies ($0 < z < 3.7$) to measure cosmic acceleration and constrain the properties of dark energy, while also detecting fast radio bursts at an unprecedented rate ($\gtrsim 10$ per day) and localization precision (~ 1 milliarcsecond). Additional science goals include finding thousands of new pulsars—an expected fivefold increase compared to the existing catalogue, contributing to current efforts to detect gravitational waves through pulsar timing—mapping cosmic magnetism, probing neutrino masses through matter clustering at high resolution, and more [1, 2].

In this talk, we present the scientific and engineering constraints that determine CHORD's array layout, dish shape, and feed design, with a focus on the theoretical concepts, electromagnetic simulations, and laboratory work that inform those decisions. To meet the constraints, we introduce new technology and innovative design choices. We show how very short baselines maximize sensitivity to low k-modes of the matter power power spectrum, and minimize the transient search cost. We examine the trade-offs of array compactness, such as dish shadowing and antenna-to-antenna coupling, and we present novel methods to mitigate them, such as deepening the dishes below $f/.25$. We introduce a new ultra wideband feed design that adequately illuminates those deep dishes over a 5:1 band, has very low dielectric loss, and can be mass produced at low cost. We summarize recent attempts at increasing coverage of the UV plane, explain how those attempts are in tension with efforts to maximize beam redundancy, and show how that tension can be attenuated by the same methods we use to decrease antenna-to-antenna coupling.

References

[1] P. Barmby et al., "Discovery at the Cosmic Frontier: Canadian Astronomy Long Range Plan 2020-2030", *Canadian Long Range Plan for Astronomy and Astrophysics White Papers*, May 2021, pp. 90–91, doi:10.5281/zenodo.4891064.

[2] K. Vanderlinde et al., "The Canadian Hydrogen Observatory and Radio-transient Detector (CHORD)," *Canadian Long Range Plan for Astronomy and Astrophysics White Papers*, October 2019, p. 28, doi:10.5281/zenodo.3765414.