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Multi-Messenger Probes of First-Order Phase Transitions

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Any particle physics model exhibiting symmetry breaking is necessarily accompanied by a phase transition taking the particle content of the universe from its initially symmetric phase to one where the underlying gauge symmetry is "broken". First-order phase transitions (FOPTs) are characterized by the rapid expansion of bubbles containing the new broken phase, which nucleate stochastically throughout space and eventually overtake the old symmetric phase. This violent transportation of matter and energy on cosmological scales invariably produces a stochastic background of gravitational waves (GW). If strong enough, signals from these GW may be detectable by upcoming experiments, offering a probe of an early universe as yet unobserved. Near the end of a FOPT, matter may be trapped within contracting pockets of the old phase, potentially leading to primordial black hole (PBH) formation. This provides additional probes as the PBHs may be evaporating and releasing detectable Hawking radiation. Furthermore, if the PBHs have not completely evaporated, they are expected to make up some fraction of the dark matter and are subject to abundance constraints.

This talk studies these multimessenger probes of the early universe in the context of conformal $B-L$ models. The underlying $B-L$ gauge symmetry is broken with a Higgs mechanism wherein a scalar field develops a nonzero vacuum expectation value, inducing a FOPT. Right-handed neutrinos are included in the model and become trapped in the old symmetric phase, possibly leading to PBHs. We find that not only can these models be simultaneously probed with GW signals and PBH constraints, but also different experiments can probe different energy scales within $B-L$ models as each energy scale exhibits a unique detection signature.

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