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Gravitational waves from phase transitions in the early universe

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Gravitational waves from cosmological phase transitions offer a novel probe of particle physics. As the early universe cooled, it may have undergone a phase transition from a metastable vacuum to the true vacuum. While the Standard Model of particle physics predicts continuous phase transitions during electroweak and QCD symmetry breaking, many extensions of the Standard Model predict first-order (discontinuous) phase transitions. These can provide the conditions necessary for baryogenesis and produce stochastic gravitational waves that encode information about the fields that drive the transition. Furthermore, if such a transition occurs at the electroweak scale, the resulting gravitational waves are expected to be visible to future detectors, motivating accurate calculations of gravitational wave spectra across a range of particle physics models.

Recent calculations often adopt a simplified equation of state describing the relativistic hydrodynamics of the phase transition, which impacts the shape of the gravitational wave spectrum. This relies on the assumption that the universe is radiation dominated during the phase transition, which breaks down in the true vacuum phase. Furthermore, fitting formulas used to determine the gravitational wave spectrum from hydrodynamics are not easily generalised to a generic equation of state. We propose a self-consistent method for evaluating the gravitational wave spectrum from a particle physics model using the exact equation of state and without fitting formulas. We perform these calculations across select regions of parameter space for simple extensions of the Standard Model to demonstrate the difference in the shape of the resulting gravitational wave spectra.

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