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Moon as a Gravitational-Wave Detector

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The increasing interest in detecting gravitational waves (GWs) in the decihertz (0.1 Hz) band has inspired the exploration of novel detection methodologies. The Moon, with its substantial mass and low ambient seismic noise, has long been regarded as a promising natural resonant detector for decihertz GWs. Recent proposals for lunar seismology missions—such as China's Chang'e program and Europe's Lunar Gravitational-Wave Antenna (LGWA)—require a precise theoretical framework for the Moon's dynamical response to incident GWs. However, prior analyses have yielded two distinct response functions: one derived from a field-theoretic treatment and the other based on tidal deformation theory, prompting questions regarding their physical equivalence.

In this talk, I will present a unified analytical and numerical treatment of the Moon's normal modes under GW excitation. I will demonstrate that the two response functions are fundamentally identical, with apparent discrepancies arising solely from gauge-dependent coordinate choices. Employing the correct formulation, we reassess the sensitivity of proposed lunar seismometer arrays, revealing a flatter response spectrum in the 0.001–0.1 Hz band compared to earlier predictions. Based on such response functions, I will discuss the detectability of a stochastic GW background using lunar seismic networks, deriving updated angular response (pattern) functions and overlap reduction functions while relaxing previous idealizations in instrument modeling.

To address the challenges posed by the Moon's structural inhomogeneity, I will show results from our 2D spectral-element-method (SEM) simulation, benchmarking its accuracy against semi-analytical solutions and systematically evaluating its limitations. These findings have provided a consolidated theoretical foundation for lunar GW response modeling, refined scientific targets for future lunar GW observations, and laid down critical design constraints for next-generation lunar GW detectors.

Collaboration you are representing

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