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The Role of r-Modes in Pulsar Spindown, Pulsar Timing, and Gravitational Waves

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Pulsars are fast-spinning neutron stars that lose their rotational energy via various processes such as gravitational and electromagnetic radiation, particle acceleration, and mass loss processes. Pulsar energy dissipation can be quantified by a spin-down equation that measures the rate of change of pulsar rotational frequency as a function of the frequency itself. We explore the pulsar spin-down equation and consider the spin-down term up to the seventh order in frequency. The seventh-order spin-down term accounts for energy carried away in the form of gravitational radiation due to a current-type quadrupole in the pulsar induced by r-modes. We derive analytical formulae of pulsar r-mode gravitational wave frequency in terms of pulsar compactness, tidal deformability, r-mode amplitude, and gravitational wave amplitude. We find solutions to the above relationships using the Lambert-Tsallis and Lambert-W functions. We also present an analytic solution of the pulsar rotational period from the spin-down equation and numerically verify it for the Crab pulsar PSR B0531+21. Accurate analysis of pulsar energy loss, spin-down, and gravitational wave emission are relevant for precise pulsar timing. The search for continuous gravitational waves with 3-rd generation ground-based and space-based gravitational wave detectors will provide additional insights to determine a more accurate neutron star equation of state.

Keyword-1

Pulsar Timing Array

Keyword-2

r-Modes

Keyword-3

Gravitational Waves

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