NATIONAL CENTRE FOR NUCLEAR RESEARCH

Abstract

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Gravitational dipole and quadrupole radiation from pulsars

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Abstract in English

This thesis presents dipole and quadrupole gravitational radiation from pulsars. Einstein's general theory of relativity (GR) predicts only two tensor polarization states dominated by the time-varying quadrupole moment. But a generic metric theory of gravity can also possess scalar and vector polarization states. This thesis focuses on Brans-Dicke (BD) theory, which attempts to modify GR by varying gravitational constant G and has three polarization states. First, we acquire polarization states in BD theory by linearizing the field equations and applying gauge conditions. Then, we employ these formulae to derive the response of a laser interferometric detector to the GW signal from a spinning neutron star in BD theory. Next, we obtain a statistic ($\mathcal{D}$-statistic) established on the maximum likelihood principle to determine the signal in BD theory in the detector's noise. This statistic generalizes the well-known $\mathcal{F}$-statistic used in the case of GR. Eventually, we perform Monte Carlo simulations in Gaussian noise to test the detectability of the signal and the precision of estimation of its parameters. Our theoretical framework is executed to probe for the scalar and tensor continuous waves in the LIGO-Virgo O2 and O3 data. We comb for continuous GWs from 23 pulsars at once and twice the spin frequencies both in BD theory and GR. No signal is found in the data, but we could impose better constraints on amplitudes.

Chapter 1 consists of some of the sections from the paper *Królak, A and Verma, P. Recent Observations of Gravitational Waves by LIGO and Virgo Detectors, Universe 2021, 7(5), 137*. Chapters 2, 3 and 4 are based on the paper *Verma, P. Probing Gravitational Waves from Pulsars in Brans-Dicke Theory, Universe 2021, 7(7), 235*. Chapter 5 summarizes the result and theory behind the LIGO-Virgo-KAGRA paper *Searches for Gravitational Waves from Known Pulsars at Two Harmonics in the Second and Third LIGO-Virgo Observing Runs, ApJ 2022 , 935, 1*. Appendix A of this thesis discusses the decomposition of the moment of inertia in symmetric trace-free (STF) tensors and spherical harmonics, which is the basis for subsection 3.1.1 of chapter 3. Appendix B summarizes the formulae of the well-known χ^2 distribution. Appendix C is about estimating parameters if a signal is detected and shows the calculation of Fisher and Covariance matrices for a monochromatic wave. It also contains the proof of the fact hat $2 \times \mathcal{F}$-statistic is a χ^2 distribution. Finally, appendix D presents the computation of the total power emitted by the scalar wave in BD theory and tensor wave in general relativity and it uses the paper *Verma, P. A swinging rod in Brans-Dicke Theory, Annalen der Physik, andp.202100600*. These formulae of power are then used to calculate the spin-down limits, one of the essential quantities for data analysis.