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Report on doctoral thesis by Paritosh Verma
“Gravitational dipole and quadrupole radiation from pulsars”

This thesis is dedicated to the analysis of observations of gravitational radiation coming from a class of pulsars. The theoretical part goes beyond the Einsteinian General Relativity — the Author considers its extension known as the Brans-Dicke theory. Reported results have been partially published in a sequence of papers. Three of them are theoretical in nature — two authored by P. Verma and one in collaboration with his supervisor Andrzej Królak. One paper is observational — this is a Ligo-Vigro-Kagra publication on the search of gravitational waves coming from known pulsars. The basic part of the thesis consists of more than 100 pages and a solid bibliography of more than 60 positions.

The first chapter is dedicated to a brief review of possible astronomical sources of gravitational radiation and of their detectors.

The second chapter discusses the main difference between the Einsteinian General Relativity and the Brans-Dicke theory. The Author uses the so-called Jordan-Fierz frame. In the Brans-Dicke theory appears the additional degree of freedom, that is connected with the existence of nonminimally coupled scalar field. In addition to the two standard polarizations, “+” and “x”, there emerges the scalar field polarization. This would lead to a new class of observational effects — “breathing” modes.

The next chapter gives a short account of neutron stars as possible sources of gravitational radiation within the Brans-Dicke theory. That includes also a concise description of needed elements of statistical analysis, that bases mainly on the book of Jaranowski and Królak.

Chapter four presents results of Monte Carlo simulations of earlier defined statistics in the Gaussian noise. The main conclusion is that only signals with a sufficiently large signal

to noise ratio, pass the Monte Carlo test.

Chapter five constitutes the main part of the thesis. It is dedicated to the search of gravitational waves from known pulsars, within the Einstein and Brans-Dicke theories, in O2 and O3 observational runs of interferometric detectors LIGO and Virgo. Paritosh Verma is a member of the project Virgo, and had been responsible for the analysis of related observational data within the consortium LIGO-KAGRA-Virgo. The obtained results have been published in the article *Searches for Gravitational Waves from Known Pulsars at Two Harmonics in the Second and Third LIGO-Virgo Observing Runs* (Astrophysical Journal 2022). The results are essentially negative — there are no detections of gravitational signals coming from pulsars. Nevertheless, they give new stronger estimates on the amplitudes of gravitational signals coming from these sources, and this a useful information, since it gives indications for future upgrading of observational interferometers.

The remaining part of the doctoral thesis consists of four appendices. Two of them give a short description of calculating gravitational wave signals, and two appendices describe elements of statistical theory of detected signals.

My overall impressions after reading the thesis are positive. Mr Paritosh Verma included the most needed elements of the gravitational wave theory and of their detection. There are his own contributions (papers published in internationally recognized journals: two in *Universe* and one in *Annalen der Physik*) — on the gravitational radiation in the Brans-Dicke theory — to the theoretical part of the dissertation. I already pointed out his crucial role in the preparation of the observational paper that constitutes the base for Chapter 5. It is clear that Mr Paritosh Verma is a competent researcher and managed to learn sophisticated tools of modern gravitational physics.

It is inevitable, that there must appear misprints. I found a few of them. On page 2, the inscription of Fig. 1 refers to black drawings of cross and plus polarizations; but in fact they are in green. Furthermore, we have *precision* instead of *precession* in the line 4 of page 10. I think also there there should be *encoded* instead of *decoded* in line 6 on page 14. This list can be continued, but I shall stop here. It is important that these mistakes and misprints do not obscure the message of the text, and their total number is reasonable as for the text of the length exceeding 100 pages.

The thesis is clearly written. There is a small Section entitled “Acknowledgements”; it is really written with bravura. I had an opportunity to listen to the talk of Mr Verma, and I

know that he is a good speaker.

In conclusion, the thesis “Gravitational dipole and quadrupole radiation from pulsars” by Paritosh Verma satisfies all requirements of the PhD thesis and I recommend initiating next stages of the PhD procedure.