UCD School of
Mathematics and Statistics

Scoil na
Matamaitice agus na Staitisticí UCD

University College Dublin
Belfield, Dublin 4, Ireland

An Coláiste Ollscoile, Baile Átha Cliath
Belfield, Baile Átha Cliath 4, Eire

T +353 1 716 2543
F +353 1 716 1172

barry.wardell@ucd.ie
www.ucd.ie/mathstat/

Report on PhD thesis of Viktor Skoupý

Dear PhD Exam Committee,

This letter constitutes my report on the PhD thesis of Viktor Skoupý, who will defend his thesis on October 27th 2023.

The thesis addresses the important problem of generating gravitational wave templates for "extreme mass ratio inspirals", binary black hole systems with a highly-asymmetric mass ratio. The work is very timely and will contribute to the success of the European Space Agency's LISA mission, which is expected to launch in the next decade.

The thesis addresses three specific aspects of the problem of producing a gravitational-wave template for extreme mass ratio inspirals:

1. Computing the flux of gravitational-wave radiation from spinning bodies in an equatorial orbit around a Kerr black hole.
2. Equatorial-orbit inspirals of spinning bodies into a Kerr black hole, to leading adiabatic order.
3. Computing the flux of gravitational-wave radiation from spinning bodies in a generic orbit around a Kerr black hole.

Each of these projects led to the publication of an article in the prestigious "Physical Review D" journal. The first two were authored by the student and his supervisor alone, and the last project was completed in collaboration with researchers at MIT.

Overall the thesis is well written, for the most part containing only minor, non-propagating typographical errors. There are also a few minor errors and places where further clarification would be helpful. For example, statements that could be clarified include:

- Page 3: it is stated that LIGO-Virgo-KAGRA operates in the kHz frequency band, but their best sensitivity and many observed sources have been lower frequency, in the region of a few hundred Hz.
- Page 7: It is stated that "the expansion can be truncated at the dipole level" but there is no justification for this, and it is possible that at least the quadrupole term will also be important.
- Page 16: It is not clear why $\Gamma^{\mu}_{\alpha \beta}$ should depend on the spin vector. Perhaps via the fact that it is evaluated on a worldline?
- Page 16: $\hat{K}$ is not defined.
- Page 19: It is stated that it is "not possible" to calculate the spacetime of an EMRI. This seems like too strong a statement. At most, it is highly impractical and inefficient to do so.

UCD School of
Mathematics and Statistics

Scoil na
Matamaitice agus na Staitisticí UCD

University College Dublin
Belfield, Dublin 4, Ireland

An Coláiste Ollscoile, Baile Átha Cliath
Belfield, Baile Átha Cliath 4, Eire

T +353 1 716 2543
F +353 1 716 1172

barry.wardell@ucd.ie
www.ucd.ie/mathstat/

- Page 24: There is a mention of “different definitions”, but it is not clarified what they are.
- Page 25: It is stated that the source “cannot be decomposed”. This is too strong a statement. Perhaps the intention is that the decomposition is not efficient in this case?
- Page 29: It is stated that it is “more convenient”, but there is insufficient clarification about what is more convenient about evolving (p,e,I) instead of (E, Jz, K).
- Page 30: It is stated that “we assume that the magnitude of the spin … is conserved”. Is there a justification for this assumption?
- Page 35: The system is “overconstrained”. Is there an intuitive explanation for why this is the case?
- Page 36: It is stated that the spin is of the same order as the mass ratio: sigma <= q << 1. The dimensionless spin can take on arbitrary values (within the usual astrophysical constraints of a Kerr black hole) as it is always suppressed by a factor of the mass ratio. As such, I do not see a reason why we can’t have large dimensionless spin values ~ O(1).
- Why is a fourth-order finite difference used in Eq. (4.11), but only second order in Eq. (4.8)?

A sample of the minor typographical errors include:

- Page 5: It is stated that indices run from 0 to 4. Should this be 0 to 3?
- Page 14, Eq. (1.47): $p^{(g)}(p,e)$ should be $f^{(g)}(p,e)$?
- Page 18: “geodetic” -> “geodesic”
- Page 26, Eq. (2.36): Missing $\delta \sigma$ in first term on right-hand-side?
- Page 31 first line: There is reference to Eq. (3.14). Should this be referring to a different equation?

These minor issues do not detract from the overall high quality of the thesis. The results in the thesis represent a substantial amount of progress on an important and technically challenging problem and are very worthy of the three publications in Physical Review D that they produced. The work certainly represents a level meriting the award of a PhD.

Yours sincerely,

Dr Barry Wardell
Associate Professor
School of Mathematics and Statistics
University College Dublin