



MAP-fis Essay Proposal, 2016-2017

(please write in English)

Supervisor

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Title

Astrophysical Phenomenology of non-Kerr black holes

Area

(Materials, Optics, Condensed Theory, High Energy Theory,...);

Strong Gravity

Summary of Proposal

A considerable body of evidence supports the existence of black holes (BHs) in the Universe. It is still unknown, however, if the observed BH candidates realize the paradigmatic BH of General Relativity: the Kerr solution. The next decade promises to shed light on this issue: ongoing observations are mapping the space-time geometry close to BH candidates with unprecedented accuracy. This evidence will come from i) gravitational wave astronomy, in particular with the LIGO/Virgo detectors; ii) X-ray observations with the next generation of satellites (e.g. ATHENA and eXTP); iii) large baseline interferometry, using the Event Horizon Telescope; and iv) astrometric measurements, using the GRAVITY instrument. These forthcoming experiments make it timely to explore the associated phenomenology for alternative models to the General Relativity BH paradigm. This is the purpose of this thesis, focusing on the theoretically most well established alternative models to the Kerr solution, both in and beyond General Relativity.

Studying the astrophysical phenomenology of non-Kerr black holes works in two steps: 1) Obtaining the solutions of the non-Kerr models, which is non-trivial since they are only known numerically and the data is not publicly available; 2) Studying the corresponding phenomenology.

The two advisors, Prof. Carlos Herdeiro and Dr. Eugen Radu, are very active, internationally recognized, researchers in the field of black holes.

The co-advisor, Dr. Radu is a leading expert on the field of numerical stationary black hole solutions and was one of the co-discoverers of some of the models that shall be tackled. This will guarantee the success of the aforementioned first step.

The main advisor, Prof. Herdeiro, created the gravitational physics group at Aveiro University. He



has a large experience with black hole physics at different levels, as well as in advising undergraduate and PhD students. Over the last few years Prof. Herdeiro has created a network of collaborations with leading experts on exploring the astrophysical phenomenology that is the focus of this thesis. This includes the collaboration on electromagnetic properties such as the X-ray spectrum (Shanghai-China group working on the K-alpha line and the Rome-Italy group working on Quasi-Periodic-Oscillations) and black hole lensing (Paris-Meudon group that developed the Giotto code and the ESA group that developed the Pyhole code). The student will greatly benefit from this network. The participation of the Aveiro group on an ongoing international Marie Curie RISE network and a COST action, both focusing on gravitational waves, will allow the student to visit international institutions such as Cambridge University (UK), Perimeter Institute (Canada), U. Mississippi (USA) and Osaka University (Japan). All these partnerships will contribute to the success of the second step. The necessary computational resources are available in Aveiro: the computational clusters BlaFis and (the new) Argus.

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References

(to allow students first look at topic)

Review paper on testing the Kerr metric with Astrophysical observations:

[1] E. Berti et al., *Class. Quant. Grav.* 32 (2015) 243001, arXiv:1501.07274 [gr-qc].

Review paper on alternative black hole models:

[2] C. A. R. Herdeiro and E. Radu, *Int. J. Mod. Phys. D* 24 (2015) no.09, 1542014, arXiv:1504.08209 [gr-qc].

Examples of papers of the Aveiro group on black hole shadows:

[3] P. V. P. Cunha, C. A. R. Herdeiro, E. Radu and H. F. Runarsson, *Phys. Rev. Lett.* 115 (2015) no.21, 211102, arXiv:1509.00021 [gr-qc].

[4] F. H. Vincent, E.ourgoulhon, C. Herdeiro and E. Radu, *Phys. Rev. D* 94 (2016) no.8, 084045, arXiv:1606.04246 [gr-qc].



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Examples of papers of the Aveiro group on the iron-line technique:

[5] Y. Ni, M. Zhou, A. Cardenas-Avendano, C. Bambi, C. A. R. Herdeiro and E. Radu, JCAP 1607 (2016) no.07, 049, arXiv:1606.04654 [gr-qc].

[6] M. Zhou, C. Bambi, C. A. R. Herdeiro and E. Radu, Phys. Rev. D 95 (2017) no.10, 104035, arXiv:1703.06836 [gr-qc].

Examples of papers of the Aveiro group on Quasi-Periodic-Oscillations:

[7] N. Franchini, P. Pani, A. Maselli, L. Gualtieri, C. A. R. Herdeiro, E. Radu and V. Ferrari, Phys. Rev. D 95 (2017) no.12, 124025, arXiv:1612.00038 [astro-ph.HE].