RISE Mid-term meeting

project “Fundamental Fields and Compact Objects”,
FunFiCO 777740

July 13th 2019, Valencia

RISE mid-term meeting – project FunFiCO 777740

1. **Meeting date –** July 11th 2019 (Saturday)
2. **Meeting time –** 9- 13 am (Valencia time)
3. **Venue and participants -** Library, Depart. of Astronomy and Astrophysics, Valencia

Will be present (coordinators):

Carlos Herdeiro (Aveiro University, Portugal)
José A. Font (Valencia University, Spain)
Juan Carlos Degollado Daza (UNAM, Mexico)
Luis Carlos Crispino (Universidade Federal do Pará, Brazil)

Will join via skype:

Amanda-Jane Ozin-Hofsaess (Project Officer)
Samuel Dolan (Sheffield University, U.K.)

(Brief introduction of all participants)

Will be present (project members):

Jorge Delgado (PhD student from Aveiro node)
João Oliveira (PhD student from Aveiro node)
Pedro Cunha (PhD student from Aveiro node)
Alexandre Pombo (PhD student from Aveiro node)
Gonzalo Olmo (Staff from Valencia node)
Nicholas Sanchis Gual (PhD student from Valencia node, now researcher in Lisbon)
Adrià Delhom Latorre (PhD student)
Cintia Cecilia Menchón Pérez (PhD Student)
Carolina Benone (Staff from Belém node)

Agenda:

1) Project status (coordinator);

a) Scientific aspects (WG leaders)

b) Management aspects+ scientific/training/dissemination achievements (coordinator)

2) Testimonies from seconded staff (various seconded people)

3) Planning for the remaining period (node coordinators)

Agenda:

1) Project status (coordinator);

a) Scientific aspects (WG leaders)

* Scientific/socio-economic reasons for carrying out this research (pro memoria)

* Scientific highlights of the work carried out so far.

* Unexpected additional results

Agenda:

1) Project status (coordinator);

a) Scientific aspects (WG leaders)

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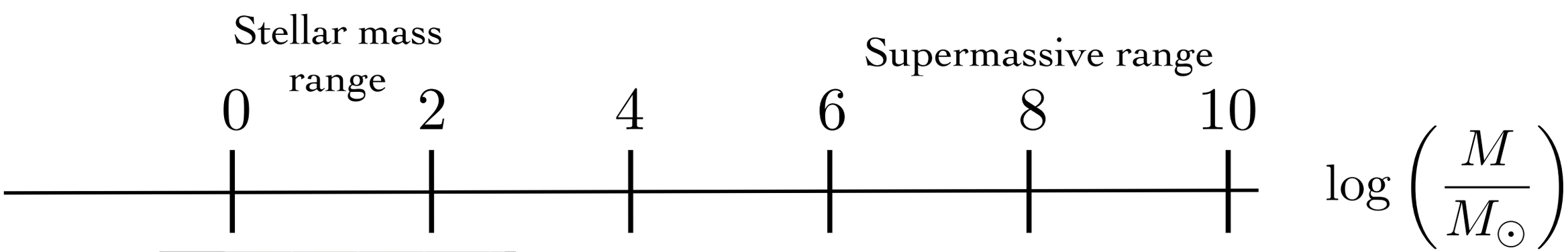
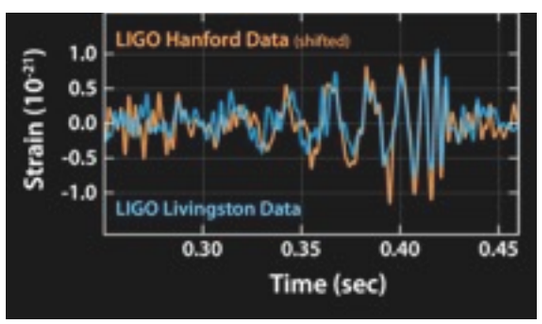
* Scientific highlights of the work carried out so far.

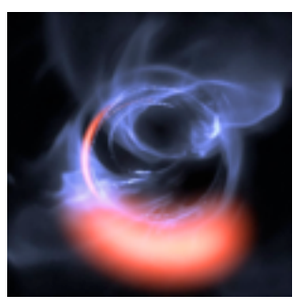
* Unexpected additional results

We live one of the most exciting period on the understanding of the strongest gravity regions in the Universe!





LIGO/Virgo



Gravity

Event Horizon Telescope

Agenda:

1) Project status (coordinator);

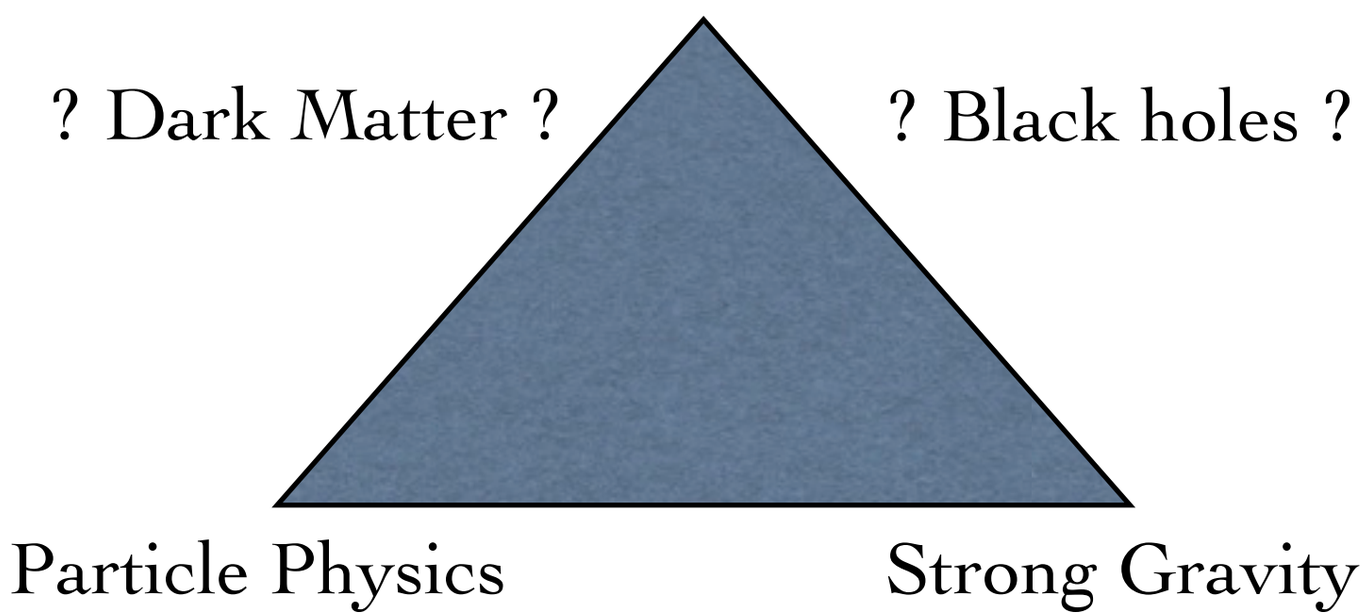
a) Scientific aspects (WG leaders)

* Scientific/socio-economic reasons for carrying out this research (pro memoria)

* Scientific highlights of the work carried out so far.

* Unexpected additional results

Yet... in the construction of our scientific understanding of Nature, deep mystery remain.



Agenda:

1) Project status (coordinator);

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* Scientific/socio-economic reasons for carrying out this research (pro memoria)

* Scientific highlights of the work carried out so far.

* Unexpected additional results

Obtaining hints on the true nature of compact objects, strong gravity and particle physics beyond the standard model, using the latest theoretical and observational developments is the goal of the:

RISE Project

"Fundamental Fields and Compact Objects",

FunFiCO 777740

Agenda:

1) Project status (coordinator);

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* Unexpected additional results

Publications so far:

Over 60 publications in top international journals.

Phys. Rev. Lett.,
Phys. Rev. D,
Classical and Quantum Gravity,
Phys. Lett. B,
....

Screenshot from participant portal (12/7/2019)

Grant Management

Project Continuous Report

777740 (FunFiCO) MSCA-RISE

HORIZON 2020

Call: H2020-MSCA-RISE-2017

Topic: MSCA-RISE-2017 Unit: REA/A/03

Summary for publication | Deliverables Ethics, DMP, Other Reports | Milestones | Critical Risks | Publications | Disseminat... | Patents (IPR) | Gender | Researchers | ABS Regulation

Publications

Include previously discarded publications

No.	Type	Title	Authors	Title of the Journal/Proc./Book	Date of Acceptance
3	Other	Comment on "Geodesic dynamics on Chazy-Curzon spacetimes"	Dolan, Sam R.		04/01/2019
4	Other	Universal relations for gravitational-wave asteroseismology of pr	Torres-Forné, Alejandro; Cerdá-Durán,		26/02/2019
5	Other	Novel couplings between nonmetricity and matter	Lobo, Francisco S. N.; Harko, Tiberiu;		03/01/2019
6	Other	Higher-order geometrical optics for electromagnetic waves on a	Dolan, Sam R		07/01/2018
7	Other	Spontaneous scalarisation of charged black holes: coupling deper	Fernandes, Pedro G. S.; Herdeiro, Carl		13/02/2019

Project publications (56 publications)

No.	Type	Title	Authors	Title of the Journal/Proc./Book	Number, date or freq. of the Journal/Proc./Book	Is Peer-reviewed?	Is O Acc
47	Article in Jc	On the topological charge of $SO(2)$ gauged Skyrmions in	Navarro-Lerida, Francisco; Radu, E	Phys Lett B	15	Yes	Green
48	Article in Jc	Vacuum polarization on topological black holes	Morley, T.; Taylor, P.; Winstanley,	0264-9381	14	Yes	Green
49	Article in Jc	Boson and Dirac stars in D ≥ 4 dimensions	Jose Luis Blázquez-Salcedo, Christi	Physics Letters B	793	Yes	Green
50	Article in Jc	Structure and thermodynamics of charged nonrotating bla	Benbellout, H.; Diaz-Alonso, J.; Ru	Phys.Rev.D, 2019, 99 (8), pp.084027. &#x27E8	10	Yes	Green
51	Article in Jc	Correspondence between modified gravity and general rel	Victor I. Afonso, Gonzalo J. Olmo,	Physical Review D	99/4	Yes	Green
52	Article in Jc	Spectral lines of extreme compact objects	Caio F. B. Macedo, Tom Stratton, S	Physical Review D	98/10	Yes	Green
53	Article in Jc	Black holes with surrounding matter and rainbow scatterir	Luiz C. S. Leite, Caio F. B. Macedo,	Physical Review D	99/6	Yes	Green
54	Article in Jc	Massive and charged scalar field in Kerr-Newman spacetim	Carolina L. Benone, Luís C. B. Crisp	Physical Review D	99/4	Yes	Green
55	Article in Jc	Global monopole in Palatini f (R) gravity	J. R. Nascimento, Gonzalo J. Olmo	Physical Review D	99/6	Yes	Green
56	Article in Jc	Self-gravitating magnetized tori around black holes in gen	Patryk Mach, Sergio Gimeno-Soler,	Physical Review D	99/10	Yes	Green

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From Proposal
Part B, document 1
Mar. 31st 2017

Table B1: Work Package List

Work Package No	Work Package Title	Activity Type (e.g. Research, Training, Management, Communication, Dissemination...)	Number of person-months involved	Start Month	End month
1	Construction and physical properties of new compact objects	Research, Training, Dissemination	7	1	48
2	Phenomenology I: orbits, test fields and linear perturbations	Research, Training, Dissemination	24	1	48
3	Phenomenology II: non-linear dynamics	Research, Training, Dissemination	17	1	48

WP 1 presentation by C. Herdeiro

(WP1) Construction and physical properties of new compact objects

From Proposal
Part B, document 1
Mar. 31st 2017

Objectives

The purpose of this work package is to:
(i) Construct new COs and hairy BHs based on the synchronization mechanism;
(ii) Study some of their basic physical/mathematical properties;
(iii) Organize such solutions, including the already known ones, into usable libraries and provide them for the remaining work packages. These libraries will be made available to the community by the end of this project.

Task 1.1: Construction of BH solutions in GR and scalar/vector-tensor theories based on the synchronization mechanism. Kerr BHs with scalar hair will be considered in more generality (including more general self-interactions and GR extensions). Kerr BHs with Proca hair will be considered with possible self-interactions. Spin 2 hair will be considered. Fermionic stars will be considered. The inclusion of gauge fields will be considered in a more systematic way [35]. Synchronized hairy BHs will be considered in scalar multi-tensor theories. Models in Anti-de-Sitter or enclosed in a cavity will be considered as well as extensions to de Sitter.

Task 1.2: Investigation of physical/mathematical properties of the solutions obtained in **Task 1.1**, including the spacetime distribution of the hair field, the solitonic limit, the extremal limit, the "bald" limit where a study of stationary clouds can be performed [28], the geometry of the horizon, including embedding diagrams, thermodynamical properties, multipolar structure, existence of ergoregions and light rings and their type in Petrov's classification.

Task 1.3: Creation of a systematic library of the different families of solutions, both the ones already known [19] and the ones resulting from **WP1**, organized by physical parameters (e.g., ADM mass, angular momentum and Noether/gauge charges). Organization of a pipeline, to analyse these solutions in **WP2,** and preparing appropriate initial data for **WP3**.

PHYSICAL REVIEW LETTERS **121,** 101102 (2018)

Spontaneous Scalarization of Charged Black Holes

Carlos A. R. Herdeiro,[1] Eugen Radu,[1] Nicolas Sanchis-Gual,[2] and José A. Font[2,3]
[1]*Departamento de Física da Universidade de Aveiro and CIDMA, Campus de Santiago, 3810-183 Aveiro, Portugal*
[2]*Departamento de Astronomía y Astrofísica, Universitat de València, Carrer del Dr. Moliner 50, 46100, Burjassot (València), Spain*
[3]*Observatori Astronòmic, Universitat de València, c/Catedrático José Beltrán 2, 46980, Paterna (València), Spain*

(Received 19 June 2018; published 5 September 2018)

Extended scalar-tensor Gauss-Bonnet (ESTGB) gravity has been recently argued to exhibit spontaneous scalarization of vacuum black holes (BHs). A similar phenomenon can be expected in a larger class of models, which includes, e.g., Einstein-Maxwell scalar (EMS) models, where spontaneous scalarization of electrovacuum BHs should occur. EMS models have no higher curvature corrections, a technical simplification over ESTGB models that allows us to investigate, *fully nonlinearly*, BH scalarization in two novel directions. First, numerical simulations in spherical symmetry show, dynamically, that Reissner-Nordström (RN) BHs evolve into a perturbatively stable scalarized BH. Second, we compute the nonspherical sector of static scalarized BH solutions bifurcating from the RN BH trunk. Scalarized BHs form an infinite (countable) number of branches and possess a large freedom in their multipole structure. Unlike the case of electrovacuum, the EMS model admits static, asymptotically flat, regular on and outside the horizon BHs without spherical symmetry and even without any spatial isometries, which are thermodynamically preferred over the electrovacuum state. We speculate on a possible dynamical role of these nonspherical scalarized BHs.

DOI: 10.1103/PhysRevLett.121.101102

Physics Letters B 781 (2018) 651–655

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Effective stability against superradiance of Kerr black holes with synchronised hair

Juan Carlos Degollado [a], Carlos A.R. Herdeiro [b,*], Eugen Radu [b]

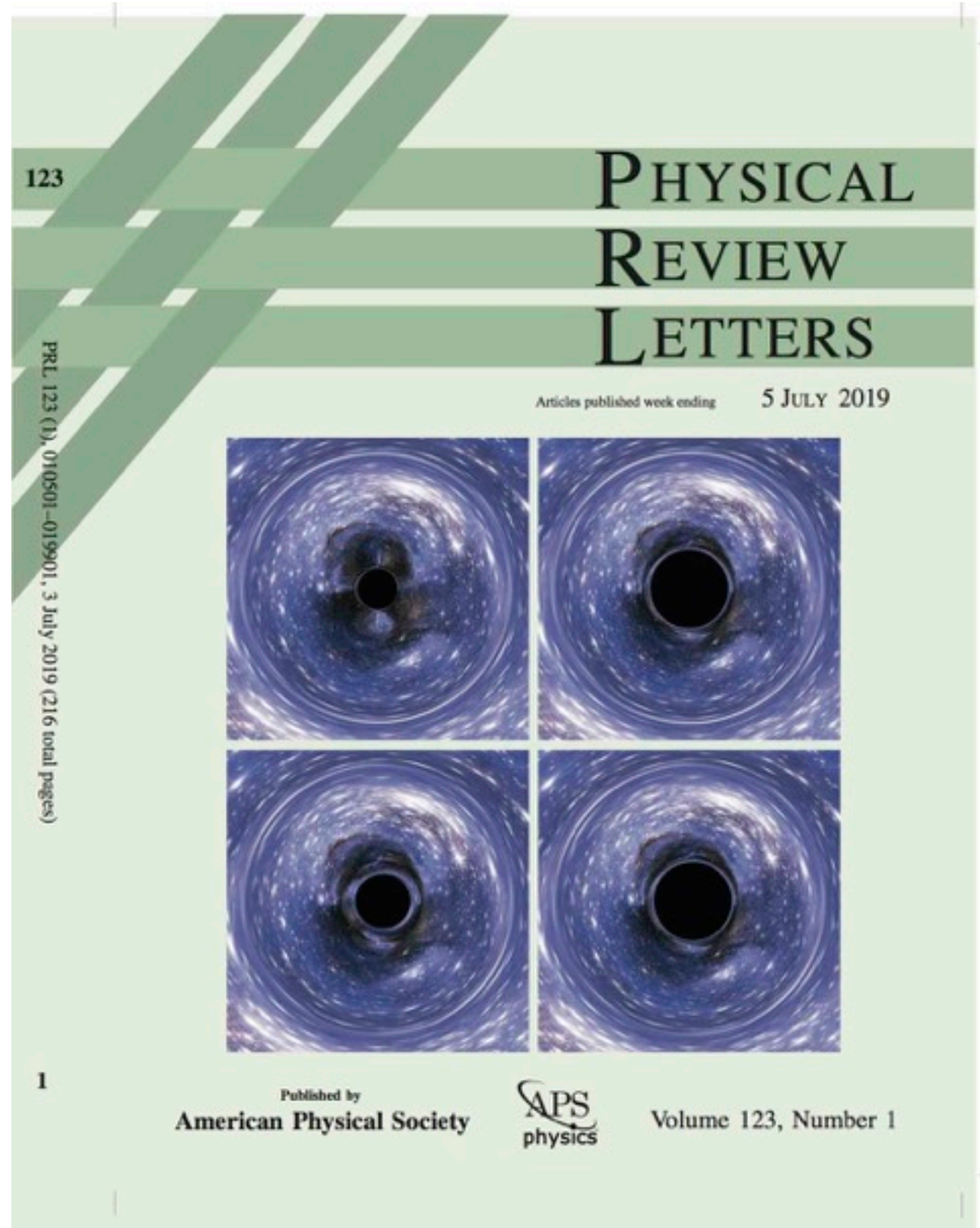
[a] Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México, Apdo. Postal 48-3, 62251, Cuernavaca, Morelos, Mexico
[b] Departamento de Física da Universidade de Aveiro and CIDMA, Campus de Santiago, 3810-183 Aveiro, Portugal

ARTICLE INFO

Article history:
Received 29 March 2018
Accepted 24 April 2018
Available online 27 April 2018
Editor: M. Cvetič

ABSTRACT

Kerr black holes with synchronised hair [1,2] are a counter example to the no hair conjecture, in General Relativity minimally coupled to simple matter fields (with mass μ) obeying all energy conditions. Since these solutions have, like Kerr, an ergoregion it has been a lingering possibility that they are afflicted by the superradiant instability, the same process that leads to their dynamical formation from Kerr. A recent breakthrough [3] confirmed this instability and computed the corresponding timescales for a sample of solutions. We discuss how these results and other observations support two conclusions: 1) starting from the Kerr limit, the increase of hair for fixed coupling μM (where M is the BH mass) increases the timescale of the instability; 2) there are hairy solutions for which this timescale, for astrophysical black hole masses, is larger than the age of the Universe. The latter conclusion introduces the limited, but physically relevant concept of *effective stability*. The former conclusion, allows us to identify an *astrophysically viable domain* of such effectively stable hairy black holes, occurring, conservatively, for $M\mu \lesssim 0.25$. These are hairy BHs that form dynamically, from the superradiant instability of Kerr, within an astrophysical timescale, but whose own superradiant instability occurs only in a cosmological timescale.



From Proposal
Part B, document 1
Mar. 31st 2017

Deliverables:

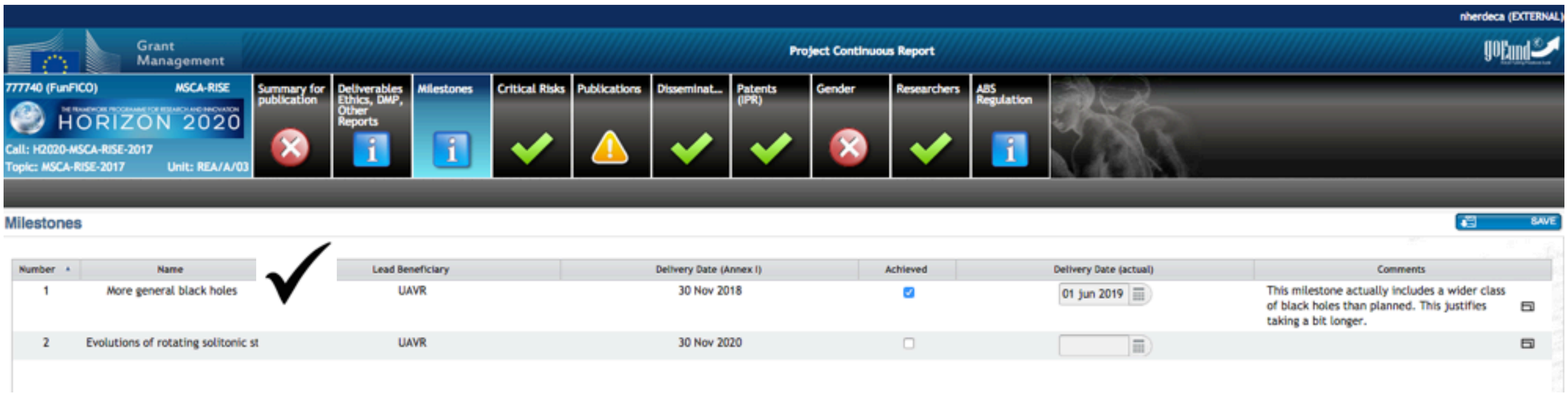
D1.1 - New SCOs and hairy BHs based on the synchronization mechanisms, with scalar and vector self-interactions and gauge charges.

D1.2 - Organized libraries of hairy solutions based on the synchronization mechanism, including information of basic physical properties, to be made publicly available by the end of this proposal, following the sample examples in [36].

Researchers involved: Carlos Herdeiro, Eugen Radu, Pedro Cunha, João Oliveira, Jorge Delgado, Alexandre Pombo, Elizabeth Winstanley, Jake Shipley, Sam Dolan, Luis Crispino, Caio Macedo, Leandro Oliveira, Carolina Benone, Luiz Leite, Juan Carlos Degollado, José Manuel Torres, Nicolás Sanchis Gual, Gonzalo Olmo

D1.1 submitted

Milestones



Number	Name	Lead Beneficiary	Delivery Date (Annex I)	Achieved	Delivery Date (actual)	Comments
1	More general black holes	UAVR	30 Nov 2018	☑	01 jun 2019	This milestone actually includes a wider class of black holes than planned. This justifies taking a bit longer.
2	Evolutions of rotating solitonic st	UAVR	30 Nov 2020	☐		

WP 2 presentation by S. Dolan

We have investigated the absorption properties of a family of nonsingular compact object solutions which arise in different metric-affine theories, such as quadratic and Born-Infeld gravity. These solutions continuously interpolate between Schwarzschild black holes and naked solitons with wormhole topology. The resulting spectrum is characterized by a series of quasibound states excitations, associated with the existence of a stable photonsphere.

This study is the first step in the characterization of the interactions between wormhole ECOs and matter fields, revealing that they present absorptive spectral features very similar to those of star-like ClePhOs. The implications of our results are two-folded: (i) They allow to distinguish ECOs from standard GR BHs at the observational level, and could also be used in order to discriminate between the different modified gravity approaches that are studied today and do not predict the existence of ECOs; (ii) They can be used to distinguish wormhole and star-like ClePhOs, since their absorption spectra have distinctive features, like the high-frequency limit.

PHYSICAL REVIEW D 100, 024016 (2019)

Absorption by black hole remnants in metric-affine gravity

Adria Delhom,[1,*] Caio F. B. Macedo,[2,†] Gonzalo J. Olmo,[1,‡] and Luís C. B. Crispino[3,§]
[1]*Departamento de Física Teórica and IFIC, Centro Mixto Universidad de Valencia—CSIC. Universidad de Valencia, Burjassot-46100, Valencia, Spain*
[2]*Campus de Salinópolis, Universidade Federal do Pará, 68721-000, Salinópolis, Pará, Brazil*
[3]*Faculdade de Física, Universidade Federal do Pará, 66075-110 Belém, Pará, Brazil*

(Received 10 March 2019; published 10 July 2019)

Using numerical methods, we investigate the absorption properties of a family of nonsingular solutions which arise in different metric-affine theories, such as qu
continuously interpolate between Schwarzschild black hol
The resulting spectrum is characterized by a series of qu
existence of a stable photonsphere.

DOI: 10.1103/PhysRevD.100.024016

I. INTRODUCTION

In the last years there has been increasing interest in the study of compact objects which may figure as astrophysical alternatives to classical black holes (BHs) or exhibit unconventional features, such as hair or signs of new high-energy physics [1–6]. This interest has grown in parallel with the development of gravitational wave detectors, which have provided convincing evidence that collisions between massive astrophysical-size compact objects is a fact [7–12]. However, the current capabilities of such observatories are yet insufficient to confirm or rule out the existence of the BH event horizon itself and we will have to wait for future developments in order to have a chance to settle this issue, as

ACKNOWLEDGMENTS

The authors would like to acknowledge partial financial support from the European Union's Horizon 2020 research and innovation programme under the H2020-MSCA-RISE-2017 Grant No. FunFiCO-777740. We also thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)—Finance Code 001, from Brazil, for partial financial support. A. D. and G. J. O. thank Universidade Federal do Pará for kind hospitality. A. D. is supported by a PhD contract of the program FPU 2015 (Spanish Ministry of Economy and Competitiveness) with reference FPU15/05406. G. J. O. is funded by the Ramon y Cajal contract RYC-2013-13019 (Spain). This work is supported by the Spanish projects FIS2014-57387-C3-1-P and FIS2017-84440-C2-1-P (MINECO/FEDER, EU), the project SEJI/2017/042 (Generalitat Valenciana), the Consolider Program CPANPHY-1205388, and the Severo Ochoa Grant No. SEV-2014-0398 (Spain).

PHYSICAL REVIEW D 98, 104034 (2018)

Spectral lines of extreme compact objects

Caio F. B. Macedo,[1] Tom Stratton,[2] Sam Dolan,[2] and Luís C. B. Crispino[3]
[1]*Campus Universitário Salinópolis, Universidade Federal do Pará, 68721-000, Salinópolis, Pará, Brazil*
[2]*Consortium for Fundamental Physics, School of Mathematics and Statistics, University of Sheffield, Hicks Building, Hounsfield Road, Sheffield S3 7RH, United Kingdom*
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(Received 20 July 2018; published 21 November 2018)

We study the absorption of scalar fields by extreme/exotic compact objects (ECOs)—horizonless alternatives to black holes—via a simple model in which dissipative mechanisms are encapsulated in a single parameter. Trapped modes, localized between the ECO core and the potential barrier at the photonsphere, generate Breit-Wigner-type spectral lines in the absorption cross section. Absorption is enhanced whenever the wave frequency resonates with a trapped mode, leading to a spectral profile which differs qualitatively from that of a black hole. We introduce a model based on Nariai spacetime, in which properties of the spectral lines are calculated in closed form. We present numerically calculated absorption cross sections and transmission factors for example scen essential features. We argue that, in principle, ECOs ca absorption spectra.

DOI: 10.1103/PhysRevD.98.104034

I. INTRODUCTION

The recent detections of gravitational waves (GWs) have reinforced the position of general relativity (GR) as the canonical theory of gravity [1–4]. In the GW150914 event, the loudest thus far, no significant evidence for violations of GR has been found [5,6], and the dynamics appears fully consistent with the coalescence of two black holes (BHs). In 2017, alternative theories of gravity were strongly constrained by the near-coincident arrival of GWs and

ACKNOWLEDGMENTS

The authors would like to thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)-Finance Code 001, from Brazil, for partial financial support. This research has also received funding from the European Union's Horizon 2020 research and innovation programme under the H2020-MSCA-RISE-2017 Grant No. FunFiCO-777740. S. D. acknowledges financial support from the Engineering and Physical Sciences Research Council (EPSRC) under Grant No. EP/M025802/1 and from the Science and Technology Facilities Council (STFC) under Grant No. ST/P000800/1.

Physics Letters B 786 (2018) 442–447

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Synchronized stationary clouds in a static fluid

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Keywords:
Stationary clouds
Analogue models of gravity
Black holes

ABSTRACT

The existence of stationary b
cylinders is established. We a
associated field, is sufficient
existence of infinitely long liv
such stationary clouds for so
rotates with constant angula
experimental observation of
rotating black holes and blac
condition between Ω and the

Acknowledgements

This study was financed in part by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES, Brazil) – Finance Code 001, and by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, Brazil), grants FA 308863/2014-3 and FA 309749/2017-4. This work has been supported by the FCT (Portugal) IF programme and grant PTDC/FIS-OUT/28407/2017, the CIDMA (FCT) strategic project UID/MAT/04106/2013 and by the European Union's Horizon 2020 research and innovation (RISE) programmes H2020-MSCA-RISE-2015 Grant No. StronGrHEP-690904 and H2020-MSCA-RISE-2017 Grant No. FunFiCO-777740. The authors would like to acknowledge networking support by the COST Action CA16104. M.R. acknowledges partial support from the São Paulo Research Foundation (FAPESP), Grant No. 2013/09357-9.

Deliverables

D2.1 – ISCO and properties of stable bound orbits periastron precession and nodal precession frequencies around hairy BHs and other COs

D2.2 – Thorough studies of hairy BHs shadows and iron line shapes in different models

D2.3 - Scattering and absorption properties of isolated, acoustic analogue and hairy BHs and other COs

D2.4 - Determination of the frequencies of oscillations of scalar and vectorial test fields around hairy BHs and BHs with internal structure, including timescales for instabilities, when present

D2.5 - Templates of gravitational wave signals of perturbed hairy BHs and COs made up of FBFs

Researchers involved: Luis Crispino, Caio Macedo, Leandro Oliveira, Carolina Benone, Luiz Leite, Rafael Bernar, Amanda Almeida, Ivanildo Gomes Jr, Sam Dolan, Jake Shipley, Tom Stratton, Jake Percival, Carlos Herdeiro, Juan Carlos Degollado, Jorge Delgado, José Manuel Torres, Juan Carlos Hidalgo, Darío Nuñez, José Antonio Font, Gonzalo Olmo, Cintia Menchón

WP 3 presentation by J.A. Font

We developed a framework to study dynamical auto-gravitating bosonic fields.

In particular, we showed that the formation of Proca stars, stationary soliton-like solutions to the Einstein Equations, may be induced during an evolution setting up appropriate initial conditions.

We also characterize the gravitational wave forms produced by the head on and merger of compact objects supported by bosonic fields. The characterization was done extending a numerical code to solve numerically the Einstein equations.

PHYSICAL REVIEW D **99**, 024017 (2019)

Head-on collisions and orbital mergers of Proca stars

Nicolas Sanchis-Gual,[1] Carlos Herdeiro,[2,3] José A. Font,[1,4] Eugen Radu,[2] and Fabrizio Di Giovanni[1]

[1]*Departamento de Astronomía y Astrofísica, Universitat de València, Dr. Moliner 50, 46100, Burjassot (València), Spain*

[2]*Departamento de Física da Universidade de Aveiro and Centre for Research and Development in Mathematics and Applications (CIDMA), Campus de Santiago, 3810-183 Aveiro, Portugal*

[3]*Centro de Astrofísica e Gravitação—CENTRA, Departamento de Física, Instituto Superior Técnico—IST, Universidade de Lisboa—UL, Avenida Rovisco Pais 1, 1049-001, Portugal*

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(Received 25 June 2018; revised manuscript received 21 December 2018; published 11 January 2019)

Proca stars, *aka* vector boson stars, are self-gravitating Bose-Einstein condensates obtained as numerical stationary solutions of the Einstein-(complex)-Proca system. These solitonic objects can achieve a compactness comparable to that of black holes, thus yielding an example of a black hole mimicker, which, moreover, can be both stable and form dynamically from generic initial data by the mechanism of gravitational cooling. In this paper we further explore the dynamical properties of these solitonic objects by performing both head-on collisions and orbital mergers of equal mass Proca stars, using fully nonlinear numerical evolutions. For the head-on collisions, we show that the end point and the gravitational waveform from these collisions depends on the compactness of the Proca star. Proca stars with sufficiently small compactness collide emitting gravitational radiation and leaving a stable Proca star remnant. But more compact Proca stars collide to form a transient *hypermassive* Proca star, which ends up decaying into a black hole, albeit temporarily surrounded by Proca quasibound states. The unstable intermediate stage can leave an imprint in the waveform, making it distinct from that of a head-on collision of black holes. The final quasinormal ringing matches that of Schwarzschild black hole, even though small deviations may occur, as a signature of sufficiently nonlinear and long-lived Proca quasibound states. For the orbital mergers, we have considered eccentric orbits and the outcome also depends on the compactness of the stars. For the binaries with the most compact stars, the binary merger forms a Kerr black hole which retains part of the initial orbital angular momentum, being surrounded by a transient Proca field remnant; in cases with

From the astrophysical point of view, we studied the dynamics of an accretion disk surrounding a compact objects known as Kerr black holes with scalar hair. We have made a thorough characterization of the morphology of a magnetized disk around such compact objects and pointed out the differences with other canonical black holes.

We also investigated stationary, self-gravitating, magnetised disks around black holes by numerically solving the coupled system of Einstein's equations and the equations of ideal general-relativistic MHD. An increasing contribution of the magnetic field shifts the location of the maximum of the rest-mass density towards inner regions of the disk. The total mass and the angular momentum are affected by the magnetic field in a complex way, that depends on the black hole spin and the location of the inner radius of the disk.

PHYSICAL REVIEW D **99**, 043002 (2019)

Magnetized accretion disks around Kerr black holes with scalar hair: Constant angular momentum disks

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Testing the true nature of black holes—the no-hair hypothesis—will become increasingly more precise in the next few years as new observational data is collected in both the gravitational-wave channel and the electromagnetic channel. In this paper we consider numerically generated spacetimes of Kerr black holes with synchronized scalar hair and build stationary models of magnetized thick disks (or tori) around them. Our approach assumes that the disks are not self-gravitating, they obey a polytropic equation of state, the distribution of their specific angular momentum is constant, and they are marginally stable, i.e., the disks completely fill their Roche lobe. Moreover, contrary to existing approaches in the literature, our models are thermodynamically relativist, as the specific enthalpy of the fluid can adopt values significantly larger than unity. We study the dependence of the morphology and properties of the accretion tori on the type of black hole considered, from purely Kerr black holes with varying degrees of spin parameter, namely from a Schwarzschild black hole to a nearly extremal Kerr case, to Kerr black holes with scalar hair with different Arnowitt-Deser-Misner mass and horizon angular velocity. Comparisons between the disk properties for both types of black holes are presented. The sequences of magnetized, equilibrium disks around Kerr black holes with scalar hair discussed in this study are morphologically and thermodynamically different than their Kerr black hole counterparts, namely their vertical size is larger, the high-density central region is more extended, and the fluid is more relativistic. Therefore, we expect significant differences to appear when these sequences are used as initial data for numerical relativity codes to investigate their dynamical

We also investigated the effects of a non-convex equation of state (EOS) on the equilibrium structure of stable compact stars and on the dynamics of unstable neutron stars that collapse gravitationally to black holes, both for spherically symmetric and uniformly-rotating configurations. We showed how the dynamics of the collapse with a non-convex EOS departs from the convex case, leaving distinctive imprints on the gravitational waveforms.

We carried out the first very long-term numerical relativity simulations (extending up to 140 ms after merger) of binary neutron star mergers. At a time of 30-50 ms after merger, parts of the star become convectively unstable, which triggers the excitation of inertial modes. The excited inertial modes are potentially observable by the planned third-generation gravitational-wave detectors at frequencies of a few kilohertz.

We have started a program to study astero-seismology of core-collapse supernovae through gravitational-wave observations. We have presented the methodology of our approach and have obtained universal relations that relate the frequencies of the most common oscillation modes observed in proto-neutron stars, i.e. g-modes, p-modes and the f-mode, with fundamental properties of the system, such as the surface gravity of the proto-neutron star or the mean density in the region enclosed by the shock.

Agenda:

1) Project status (coordinator);

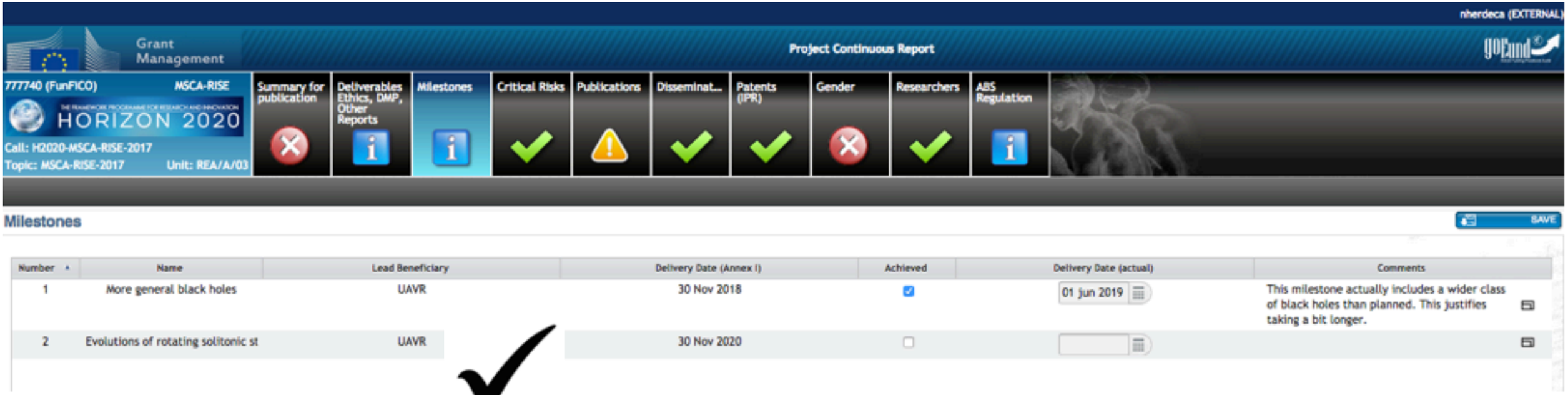
a) Scientific aspects (WG leaders)

* Scientific/socio-economic reasons for carrying out this research (pro memoria)

* Scientific highlights of the work carried out so far.

* Unexpected additional results

Milestones



Number	Name	Lead Beneficiary	Delivery Date (Annex I)	Achieved	Delivery Date (actual)	Comments
1	More general black holes	UAVR	30 Nov 2018	☑	01 jun 2019	This milestone actually includes a wider class of black holes than planned. This justifies taking a bit longer.
2	Evolutions of rotating solitonic st	UAVR	30 Nov 2020	☐		

Almost there!

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a) Scientific aspects (WG leaders)

b) Management aspects+ scientific/training/dissemination achievements (coordinator)

2) Testimonies from seconded staff (various seconded people)

3) Planning for the remaining period (node coordinators)

Overview (month 1 to 17)

From	Planned	Executed
Aveiro	8	5,29
Sheffield	7	1
Valencia	11	6,43
Total	26	12,72 (49%)

Projection (month 1 to 24)

From	Planned	Projected
Aveiro	9	5,29+4
Sheffield	7	1+1
Valencia	11	6,43+1,3
Total	27	18,02 (67%)

Issues found in months 1-24:

Aveiro node:

The coordinator moved to IST Lisbon for one year, but is returning to Aveiro in the summer 2019; this led to some rescheduling of some secondments.

Valencia node:

One secondment was postponed due to unexpected illness. One ESR moved to Lisbon University.

Sheffield node:

(1) the group has recruited fewer PhD students and post-docs than anticipated, due to a decline in UK funding environment;
(2) for various individual personal reasons it has not been appropriate for current PhD students to spend extended periods outside Europe;
(3) the permanent staff Dolan and Winstanley have not been free to travel away from Sheffield for extended periods, due to family commitments (Dolan), and senior roles at the host university (Winstanley).

Planning for months 25-48:

Aveiro node:

The planned secondments should be executed as planned with minor adjustments. Since we will have new PhD students in the group, we are planning to use 3 more secondments, transferred from the Sheffield node. These secondments will be used for the tasks planned within the working packages for which they were planned under the Sheffield node.

Valencia node:

Gonzalo Olmo will carry out 1.5 secondments in 2020 and 1.5 in 2021, both in Brazil. The PhD student Adrià Delhom will complete 1 secondment each year also in Brazil. A new PhD student, Andreu Masó, has agreed to get involved in the collaborations with Brazil and Mexico, carrying out 1 secondment on each location per year, which sums up to 2 secondments in 2020 and 2 more in 2021. The participation of Andreu will cover the secondments initially assigned to Cintia Menchón, who will no longer participate in the project, and will absorb one additional secondment per year coming from the Sheffield group. The remaining of the planning will run as initially planned, with the secondments remaining from months 1-24 being attributed to new PhD students.

Sheffield node:

Sheffield will retain 3 of its 11 remaining secondments. The remaining 8 secondments will be transferred to Aveiro (3), Lisbon (3) and Valencia (2).
Three secondments are scheduled. One is most likely to be used by a new post-doc starting in November 2019, and two by a PhD student starting in Autumn 2019.

Planning for months 25-48:

LISBON NODE ADDITION:

As an amendment to the project we would like to add Lisbon University (more concretely, Instituto Superior Técnico), as a node to the project.

Prof. Carlos Herdeiro, the global coordinator of the project, was affiliated to the University of Lisbon from Oct 2018 until the summer 2019. In this period he got funding to hire researchers and students at Instituto Superior Técnico. These researchers (currently three) are to be engaged in the activities of the project and they would greatly benefit (and so will the project) from the ability to perform secondments.

As such, we would like to make an amendment to the Grant Agreement requesting the addition of Lisbon as a node. This has the agreement of all node coordinators of the project. This node would absorb three secondments (and the corresponding tasks) from the Sheffield node.

Dissemination

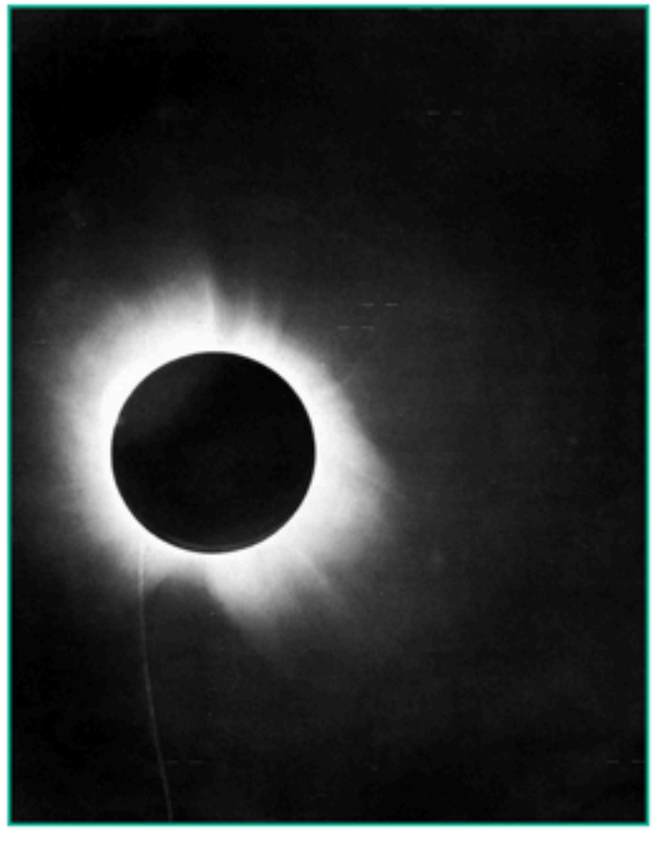
All project members are engaged in outreach. As an example, Prof. Crispino, leader of the Belém node could participate in the GR22 conference in Valencia because of the project, and participated in the outreach event on the celebrations of the centennial of the 1919 eclipse.

About Programme Speakers Venue Sponsors and Collaborators Contact

CELEBRATING 100 YEARS OF THE 1919 BRITISH ECLIPSE EXPEDITIONS – PUBLIC ASTRONOMICAL OBSERVATION
Monday, July 8, 2019 (20:00h) at the Botanical Garden of the University of Valencia

A public performance will celebrate the hundredth anniversary of the observation of the solar eclipse of 29 May 1919 from Príncipe Island, in the west coast of Africa, and Sobral, in northeastern Brazil. According to Einstein's General Relativity, light rays from distant stars passing near the Sun would bend because of the curvature of the space-time due to the presence of the Sun. The two British expeditions were the first to measure the deflection of light by massive bodies and to prove the correctness of General Relativity.

An open public space as the Botanical Garden of the University of Valencia is the perfect location for a show about the 1919 British eclipse expeditions. It will be executed by a number of contemporary-style-dressed performers. The duration of this performance will be around 20 minutes. Before the show itself, professional scientists will explain the experiment to the general public in a simple and understandable manner. Then, in a spontaneous way the performance will start accompanied by music.



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Testemonies

Will be present (project members):

Jorge Delgado (PhD student from Aveiro node)
João Oliveira (PhD student from Aveiro node)
Pedro Cunha (PhD student from Aveiro node)
Nicholas Sanchis Gual (PhD student from Valencia node, now researcher in Lisbon)
Adrià Delhom Latorre (PhD student)
Cintia Cecilia Menchón Pérez (PhD Student)
Carolina Benone (Staff from Belém node)

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From Annex 1 to the Grant Agreement (Description of the Action) Part B

1st) Kick off meeting, closed to network participants, Aveiro, 2 days, March 2018. ✓
Agenda: assessment of all work packages, establish priority list of tasks, concrete collaborative plans for tackling them and update the activities plan for this project.

Workshop/School in Mexico, Apr-May 2020

2nd) Workshop, open to the community, UNAM, Mexico, 4 days, March 2019.
Agenda: workshop devoted to non-Kerr COs phenomenology, both GWs and electromagnetic, covering WP2 and 3. Keynote speakers from both in and outside the network will participate. As output we plan to stimulate the write up of collaborative review paper.

✓ Mid term meeting/GR22

3rd) School, open to the community, Valencia, 4 days, September 2020.
Agenda: a numerical relativity oriented school for evolving BHs and other COs in the presence of matter, covering WP3. We plan to have a set of mini-lectures. The written up lectures will be published as a special volume of a well known international journal.

4th) Workshop, open to the community, Sheffield, 4 days, July 2021.
Agenda: construction and physical properties of non-Kerr COs, covering WP1. It will be timely to reassess the most promising such models, and their construction, involving numerical techniques. We plan to make public the deliverable D1.2 at this point.

Three workshops in Brazil in 2019

5th) Workshop, open to the community, Belém, 4 days, August 2022. The closing network meeting.
It will include review talks by the node coordinators covering the work in all work packages. We plan to write proceedings, as an action memory.