Robin Croft

WORK EXPERIENCE

11/2024 – Current] **Research associate in university *Sapienza, Università di Roma***

City: Roma | **Country:** Italy

- Principal Investigator : Prof. Paolo Pani
- Numerical general relativity simulations of exotic compact objects as gravitationalwave sources and gravitational phenomenology.

EDUCATION AND TRAINING

[10/2018 – 10/2022] **PhD - Applied Mathematics and Theoretical Physics**

University of Cambridge

City: Cambridge | **Country:** United Kingdom | | **Level in EQF:** EQF level 8 | **Thesis:** Numerical Modelling of the Dynamics and Gravitational Radiation of Compact Binaries in General Relativity

- Supervised by Prof. Ulrich Sperhake

[10/2017 – 08/2018] **Msci - Physics**

University of Cambridge

City: Cambridge | **Country:** United Kingdom | | **Final grade:** 1, 77.3%, rank 22. | **Le vel in EQF:** EQF level 7

- Masters thesis on point sources of electromagnetism applied to relativistic speeds and black hole spacetimes. Supervised by Prof. Steve Gull.

[10/2014 – 08/2017] **MA (matured BA) - Natural Sciences (Physics)**

University of Cambridge

City: Cambridge | **Country:** United Kingdom | | **Final grade:** 1 | **Level in EQF:** EQF level 6

RESEARCH INTERESTS

Research Interests

My research interests include black holes (BH), numerical relativity (NR), exotic compact objects (ECOs) in general relativity (GR) and gravitational wave (GW) sources. I am also an active member of the GRTL community - a growing international collaboration developing modern NR codes with adaptive mesh refinement such as GRChombo (publication P3) which I use to simulate fully nonlinear spacetimes.

During my PhD with Prof. Sperhake, I superposed and collided BS and BH solutions to observe collision phenomenology and extract GW signals. While I have experimented with BH-BS collisions my work with BS-BS collisions (publications P2, P4-P7) and BH-BH collisions (publication P1) have proved the most fruitful. I created the initial data for these simulations by reducing the Einstein equation's PDEs to ODEs (in Mathematica) which are then integrated with a shooting method (in c++) to obtain a numerical solution. I have also created proca-star and multi-boson star solutions, but these have not lead to any substantial research.

I've also spent some time developing a continuity formalism that defines a charge, it's flux through a surface and any creation/destruction of charge. This can be applied to energy, momentum, angular momentum, noether charge and more. It has proven especially useful in the measure of angular momentum possessed by a localised scalar field configuration resulting from the collision of two BSs with non-zero impact parameter (publication P4).

At the moment, as a post-doc in the University of Sapienza, I am working on EinsteinMaxwell-Scalar (EMS) black holes (EMSBH). I derived the 3+1 decomposed evolution equations for EMS theory and implemented their time evolution in GRChombo for fully non-linear GR. This required the creation of a new matter class in GRChombo to accommodate the real scalar field and real Maxwell fields. Using this code I have simulated a head-on collision of two EMSBHs. To probe GW echoes, near-extremal EMSBH solutions are needed; the numerical evolution of these spacetimes requires extreme resolution. In order to achieve this level of resolution I am developing the formalism, and writing the numerical implementation, for a dimensionally-reduced 2D-cartoon scheme suitable for evolving rotationally symmetric EMS spacetimes (e.g. head-on collisions or single EMSBH's).

Additionally I have written a time evolution code (in c++) to simulate the ringdown of perturbed EMSBHs in the linear regime for scalar and axial modes. Echoes have been observed in the time domain signals and the extracted quasi-normal modes (QNMs) are in good agreement with analytic calculations done by collaborators in the frequency domain. In the near future, working with Prof. Pani, we hope to publish these results relating to linear perturbations of EMSBHs and collisions of EMSBHs to probe GW echoes.

RESEARCH TALKS

Einstein Maxwell Scalar Black Hole Collisions and Gravitational Echoes

17th Sept 2024 at "1st TEONGRAV international workshop on theory of gravitational waves", hosted by Sapienza University.

How to Simulate a Boson Star Binary in Numerical Relativity

26th June 2024 to gravity theory working group at Sapienza University.

A Beginners Introduction to Numerical Relativity and Boson Star Mergers

29th February 2024 at a TEONGRAV seminar at the University of Milano-Bicocca.

An Introduction to Numerical Relativity and the 3+1 Formalism

7th July 2023 to gravity theory working group at Sapienza University.

Angular Momentum in Collisions of Boson Stars and Oscillatons

25th March 2021, virtual GRChombo codebase user meeting organised by following UK universities : Cambridge, KCL, Oxford, QMUL.

GRChombo and Adaptive Mesh Refinement

10 July 2019 during the "22nd International Conference on General Relativity" at Valencia, Spain.

TEACHING EXPERIENCE

Academic Supervising/Tutoring

During my PhD at DAMTP (Cambridge) I taught the following courses for supervisions:

General relativity (3 terms) and classical mechanics (1 term) to 3rd year students and mathematics (1 year) to 1st year students.

CONFERENCES AND SEMINARS

[23/09/2019 – 27/09/2019] **Kavli RISE Summer School on Gravitational Waves** Cambridge, UK

[02/09/2019 – 06/09/2019] **European Einstein Toolkit Meeting 2019** Kings College London, UK

[07/07/2019 – 12/07/2019] **22nd International Conference on General Relativity and Gravitation** Valencia, Spain

[27/05/2019 – 31/05/2019] **Higgs Centre School of Theoretical Physics 2019** University of Edinburgh, Scotland, UK

[19/11/2018 – 21/11/2018] **STFC Data Intensive Science CDT Event** University of Edinburgh, Scotland, UK

PUBLICATIONS

[2024] **[P7] Hair is complicated: Gravitational waves from stable and unstable boson-star mergers**

Reference: Bo-Xuan Ge et al.

Submitted to Phys. rev. D.

Preprint : https://arxiv.org/pdf/2410.23839

[2022] **[P6] Unequal-mass boson-star binaries: initial data and merger dynamics**

Reference: Tamara Evstafyeva et al.

Preprint : https://arxiv.org/pdf/2212.08023

[2022] **[P5] The gravitational afterglow of boson stars**

Reference: Robin Croft et al.

Preprint : https://arxiv.org/pdf/2207.05690

[2022] **[P4] Local continuity of angular momentum and noether charge for matter in general relativity**

Reference: Robin Croft

Preprint : https://arxiv.org/pdf/2203.13845

[2021] **[P3] GRChombo: An adaptable numerical relativity code for fundamental physics**

Reference: Tomas Andrade et al.

Preprint : https://arxiv.org/pdf/2201.03458

[2022] **[P2] Malaise and remedy of binary boson-star initial data**

Reference: Thomas Helfer, Ulrich Sperhake, Robin Croft, Miren Radia, Bo-Xuan Ge, Eugene A. Lim

Preprint : https://arxiv.org/pdf/2108.11995

[2021] **[P1] Anomalies in the gravitational recoil of eccentric black-hole mergers with unequal mass ratios**

Reference: Miren Radia, Ulrich Sperhake, Emanuele Berti and Robin Croft Preprint :

https://arxiv.org/pdf/2101.11015

LANGUAGE SKILLS

Mother tongue(s): English **Other language(s):**

Italian

LISTENING A2 **READING** B1 **WRITING** A2

SPOKEN PRODUCTION A2 **SPOKEN INTERACTION** A2