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# Tiago Batalha de Castro

## *Curriculum vitae and Track Record*

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### ■ Career summary

My expertise lies in cosmological simulations, including both gravity-only and hydrodynamics, focusing on modeling the outcomes of advanced cosmological simulations for application in the Bayesian analysis of cosmological probes. I have gained extensive experience in numerical techniques, cosmological analysis, and Bayesian statistics. I am a postdoctoral fellow at the Osservatorio Astronomico di Trieste. I coordinate within the Euclid Consortium key projects (KP) and work packages (WP) related to precision simulations for cluster cosmology. Under my coordination, these KP and WP have produced six papers. Recently, I was appointed as the co-coordinator of a joint KP regarding Constraining Baryonic feedback with the DR1 cosmic shear data.

I was awarded early access to the Leonardo supercomputer, fourth in the Top500 list of June 2023, and a EuroHPC Extreme Scale Access in 2024. The former project involved over 25 million CPU and 3 million GPU hours, was the only one approved in the astrophysics macro-area, and was evaluated with the highest possible score. The latter involves +20 million CPU hours and was designed to cover the computational demands for the proposed activities in the WP I coordinate inside Euclid. These projects highlight my ability to manage and optimize large-scale computational tasks and my commitment to the Euclid consortium.

In addition to my role in Euclid, I am a member of the Magneticum and the OpenGADGET collaborations. Within the Magneticum collaboration, I have co-authored five papers (two as leading author). I am also involved in developing the OpenGADGET3 code. While my primary focus has been on modeling, I have also built expertise in inferring cosmological parameters from real data. I have co-authored seven papers in this area on smaller collaborations, two of which list me as the first author. My experience in coordinating roles and supervising students at various levels has honed my organizational skills, which will be essential for the success of future projects.

In summary, my academic and professional trajectory has uniquely positioned me to lead innovative research in cosmology and astrophysics. My recent collaborative experiences have invigorated my research aspirations, and I am eager to explore new projects and ideas through collaborations and by mentoring the next generation of scientists.

### ■ Education and key qualifications:

- 2018 **Ph.D. in Physics**, FEDERAL UNIVERSITY OF RIO DE JANEIRO, Advisor: Miguel Quartin, On the Robustness of  $\Lambda$ CDM: data mining tests and cross-checks.
- 2014 **Masters degree in Physics**, FEDERAL UNIVERSITY OF RIO DE JANEIRO, Advisor: Miguel Quartin, On lensing effect in supernovae data.
- 2012 **Bachelor in Physics**, FEDERAL UNIVERSITY OF RIO DE JANEIRO.

### ■ Current Position:

- 2024 **Post-Doc**, INAF - ASTRONOMICAL OBSERVATORY OF TRIESTE.  
Group leader: Stefano Borgani

### ■ Previous Position:

- 2021-2024 **Post-Doc**, INAF - ASTRONOMICAL OBSERVATORY OF TRIESTE.  
Group leader: Alexandro Saro
- 2018 - 2021 **Post-Doc**, ASTRONOMY UNIT OF THE DEPARTMENT OF PHYSICS OF UNITS / OATS.  
Group leader: Pierluigi Monaco
- 2016 - 2017 **Ph.D. visiting student**, ASTRONOMY UNIT OF THE DEPARTMENT OF PHYSICS OF UNITS / OATS.  
Collaboration with Prof. Stefano Borgani

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## Selected papers since 2019:

1. **Castro, T.**, et al. (2024). *Euclid preparation. L. Calibration of the linear halo bias in  $\Lambda(\nu)$ CDM cosmologies.* A&A, 691, A62
2. **Castro, T.**, et al. (2024). *Euclid preparation - XXXIX. The effect of baryons on the halo mass function.* A&A, 685, A109.
3. **Fumagalli, A.**, Costanzi, M., Saro, A., **Castro, T.**, & Borgani, S. (2024). *Cosmological constraints from the abundance, weak lensing, and clustering of galaxy clusters: Application to the SDSS.* A&A, 682, A148.
4. **Burger, P. A.**, et al. (2024). *KiDS-1000 cosmology: Combined second- and third-order shear statistics.* A&A, 683, A103.
5. **Echeverri, N.**, et al. (2023). *Cosmology with One Galaxy? The ASTRID Model and Robustness.* Astrophys. J., 954, 125.
6. **Shao, H.**, et al. (2023). *A Universal Equation to Predict  $\Omega_m$  from Halo and Galaxy Catalogs.* Astrophys. J., 956, 149.
7. **de Santi, N. S. M.**, et al. (2023). *Robust Field-level Likelihood-free Inference with Galaxies.* Astrophys. J., 952, 69.
8. **Giocoli, C.**, et al. (2024). *Euclid preparation - XXXII. Evaluating the weak-lensing cluster mass biases using the Three Hundred Project hydrodynamical simulations.* A&A, 681, A67.
9. **Fumagalli, A.**, et al. (2024). *Euclid preparation - XXXV. Covariance model validation for the two-point correlation function of galaxy clusters.* A&A, 683, A253.
10. **Adamek, J.**, et al. (2023). *Euclid: Modelling massive neutrinos in cosmology – a code comparison.* JCAP, 06, 035.
11. **Shao, H.**, et al. (2023). *Robust Field-level Inference of Cosmological Parameters with Dark Matter Halos.* Astrophys. J., 944, 27.
12. **Burger, P. A.**, et al. (2023). *KiDS-1000 cosmology: Constraints from density split statistics.* A&A, 669, A69.
13. **Castro, T.**, et al. (2023). *Euclid preparation. XXIV. Calibration of the halo mass function in  $\Lambda(\nu)$ CDM cosmologies.* A&A, 671, A100.
14. **Alfradique, V.**, Quartin, M., Amendola, L., **Castro, T.**, & Toubiana, A. (2022). *The lure of sirens: joint distance and velocity measurements with third-generation detectors.* MNRAS, 517, 5449-5462.
15. **Heydenreich, S.**, Brück, B., Burger, P., Harnois-Déraps, J., Unruh, S., **Castro, T.**, Dolag, K., & Martinet, N. (2022). *Persistent homology in cosmic shear - II. A tomographic analysis of DES-Y1.* A&A, 667, A125.
16. **Marra, V.**, **Castro, T.**, Camarena, D., Borgani, S., & Ragagnin, A. (2022). *The BEHOMO project:  $\Lambda$  Lemaître-Tolman-Bondi N-body simulations.* A&A, 664, A179.
17. **Ragagnin, A.**, Fumagalli, A., **Castro, T.**, Dolag, K., Saro, A., Costanzi, M., & Bocquet, S. (2023). *Dependency of high-mass satellite galaxy abundance on cosmology in Magneticum simulations.* A&A, 675, A77.
18. **Fumagalli, A.**, et al. (2021). *Euclid: Effects of sample covariance on the number counts of galaxy clusters.* A&A, 652, A21.
19. **Martinet, N.**, **Castro, T.**, Harnois-Déraps, J., Jullo, E., Giocoli, C., & Dolag, K. (2021). *Impact of baryons in cosmic shear analyses with tomographic aperture mass statistics.* A&A, 648, A115.
20. **Harnois-Déraps, J.**, Martinet, N., **Castro, T.**, Dolag, K., Giblin, B., Heymans, C., Hildebrandt, H., & Xia, Q. (2021). *Cosmic shear cosmology beyond two-point statistics: a combined peak count and correlation function analysis of DES-Y1.* MNRAS, 506, 1623-1650.
21. **Castro, T.**, Borgani, S., Dolag, K., Marra, V., Quartin, M., Saro, A., & Sefusatti, E. (2020). *On the impact of baryons on the halo mass function, bias, and cluster cosmology.* MNRAS, 500, 2316-2335.
22. **Giocoli, C.**, Monaco, P., Moscardini, L., **Castro, T.**, Meneghetti, M., Metcalf, R. B., & Baldi, M. (2020). *Testing the Reliability of Fast Methods for Weak Lensing Simulations: WL-MOKA on PINOCCHIO.* MNRAS, 496, 1307-1324.

Castro et al. 2024a is the foundational stone for my suggested approach to modeling the impact of baryons on cosmological simulations. In this paper, I have post-processed the simulations and built the model for the impact of baryons on cluster masses and the baryonification algorithm that recovered the correct hydrodynamical masses from gravity-only simulations. In Castro et al. 2023 and Castro et al. 2024b, I designed and ran the simulations and conducted the analysis leading to a Halo Mass Function (HMF) and Halo Bias (HB) models to be used in Euclid for the inference of cosmological parameters from galaxy clusters. These models achieved a unique percent accuracy and precision, setting a new standard in the field. One of the innovative aspects of this work was the incorporation of numerical systematics into the model predictions. This required a deep

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understanding of gravity solvers and comparing their outputs and propagating errors.

Fumagalli et al. 2021 and Fumagalli et al. 2024 have developed a model for the covariance matrix of cluster abundance and cluster clustering. I oversaw the entire project (Alessandra Fumagalli was one of the Ph.D. students I co-supervised at the University of Trieste). I also coordinated the effort in the context of the Key Project/ Work Package of the Euclid Consortium. Inside Euclid, I have also coordinated the efforts as Key Project/ Work Package leader of the paper Giocoli et al. 2024.

The paper by Marra et al. 2022 presents the BEHOMO set of in-homogeneous cosmological simulations. I was responsible for training and supervising Dr. Marra during his MSCA fellowship in numerical solutions for cosmology. I have adapted codes and post-processing routines for modeling this cosmological scenario.

In Castro et al. in 2020, I led the analysis of the Magneticum simulations investigating the baryonic impact on lensing PDF and galaxy groups and cluster masses. Martinet et al. 2021 have described the impact of baryons on the inference of cosmological parameters from peak-statistics. I led the extraction of the lensing maps from Magneticum and explained the differences observed in the final results concerning the gravity-only simulations. The data cubes I extracted in Martinet et al. 2021 were widely used in a series of cosmological analyses, including the paper by Burger et al. 2024, Burger et al. 2023, Heydereich et al. 2022, and Harnois-Déraps et al. 2021, which analyzed different lensing statistics beyond two-point using a simulation-based approach.

According to inspireHEP, I have 93 citable papers, with +1000 citations, resulting in an h-index of 21. Of these, 64 are published, accumulating 946 citations and achieving an h-index of 19. My citation summary can be found in <https://inspirehep.net/authors/1701374?ui-citation-summary=true>.

## ■ Open Source Code Repositories and Software Development

- **Castro, T.** and Dakin, J. (2025). *CONCEPTSpectra*, Version 0.1. Available at: <https://github.com/TiagoBsCastro/ConceptSpectra>. DOI: <https://doi.org/https://doi.org/10.5281/zenodo.15187969>. Licensed under MIT.
- **Castro, T.** and Fumagalli, A. (2024). *CCToolkit: A Python Package for Cluster Cosmology Calculations*, Version 1.0.3. Available at: <https://github.com/TiagoBsCastro/CCToolkit> and documented at: <https://cctoolkit.readthedocs.io/>. DOI: <https://doi.org/10.5281/zenodo.13479345>. Licensed under MIT.
- **Castro, T.** (2024). *SLICER: Simulation LIght conE buildeR*, Version 2.0.1. Available at: <https://github.com/TiagoBsCastro/SLICER> and documented at: <https://tiagobscastro.github.io/SLICER/>. DOI: <https://doi.org/10.5281/zenodo.11048430>. Licensed under GPL-3.0.

## ■ Peer recognition:

### International Collaborations:

Since 2021 Euclid: Coordinator of the Precision Simulations for Cluster Cosmology Pre-Launch Key Project

Since 2021 Euclid: Deputy coordinator of the Cluster Simulations Work Package

Since 2024 Euclid: Coordinator of the Cluster Simulations Work Package

Since 2024 Euclid: Co-Coordinator of the joint Key-Project on Constraining Baryonic Feedback with cosmic shear

2022-2023 J-PAS: Coordinator of the Early Career Researchers group

Within the Euclid consortium, I have been entrusted with outlining the pre-launch papers vital for the cosmological analysis of galaxy clusters. My responsibilities extend beyond academic contributions; they involve complex managerial tasks such as coordinating diverse research groups, identifying paper leaders, and resolving conflicts. This role has required me to exercise high management skills, mainly due to the non-hierarchical relations involved, differing from traditional student or postdoc supervision. Under my coordination, the group has successfully published six papers.

In the J-PAS collaboration, my role was multi-faceted, encompassing the organization of events for Early Career Researchers, mentorship during application processes, and collaboration with the JPAS board to evaluate contributions effectively.

All the mentioned roles were awarded to me through competitive open calls, underscoring the high regard in which my peers hold my expertise and leadership skills.

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### Awards and Grants:

- 2023 Mini-Grant, INAF, 17.000,00 €
- 2017 Doutorado Nota 10, Ph.D. excellence fellowship, FAPERJ, 37.480,00 R\$
- 2015 Science without borders Ph.D. visiting fellowship, CNPQ, 65.273,66 R\$

The Mini-Grant from INAF was awarded through an Italian national peer evaluation process for Fundamental Astrophysics and is designated to cover my travel expenses for the upcoming year. The ‘Doutorado Nota 10’ is a regional award, where each department from universities in Rio de Janeiro selects its most outstanding Ph.D. candidate in their final year. The Science Without Borders fellowship was awarded through a Brazilian national call and funded my visiting period to Trieste. It is worth noting that funding opportunities in Italy are often highly restrictive, particularly for researchers without permanent positions. Despite these constraints, I secured the Mini-Grant from INAF in the only call I was eligible for, underscoring the competitiveness and quality of my research proposals.

### HPC awards:

PI of one EuroHPC Extreme Scale Access project approved for allocation of supercomputing time at CINECA (+ 20M core hours).

PI of 10 Projects approved for allocation of supercomputing time at CINECA (+ 7.5M core hours).

Co-PI of 1 Early Access Project approved for allocation of supercomputing time at Leonardo Booster (+ 25M core hours and +3M GPU hours).

Co-PI of 1 Early Access Project approved for allocation of supercomputing time at Leonardo DCGP (+ 20M core hours).

PI of 1 Project approved for allocation of supercomputing time at PLEIADI (+ 0.5M core hours).

PI of 2 Projects approved for allocation of supercomputing time at LNCC (+ 2.5M core hours).

Member of The300 collaboration and leader of the high-resolution simulation campaign for which we have been granted (+ 20M core hours).

Through national calls, I have secured the resources on CINECA, LNCC, and Pleiadi. The EuroHPC Extreme Scale Access was secured through a European call. Concerning the Early Access Project at Leonardo, I was the primary consumer of these resources, utilizing more than 95% of the allocated time, and the call had no nationality restrictions, highlighting its competitive nature. Additionally, I secured resources for the MareNostrum supercomputer through my role in the The300 collaboration.

### Invitation to International Conferences or Programs:

- 2025 IFPU Focus Week Workshop – The astrophysics of large-scale structures in the era of eROSITA, Euclid, SPT-3G: the emergence of the cosmic web
- 2025 Scientific Communication in Astronomy School – 3rd edition
- 2024 *Talk: Advancements in Theoretical Modeling for Euclid’s Cluster Cosmology.* on XIX Brazilian School of Cosmology and Gravitation
- 2024 *Talk: Advancements in Theoretical Modeling for Euclid’s Cluster Cosmology.* on CosmoSul VII
- 2023 *Talk: Towards precision cluster cosmology: advancements in Halo Mass Function and Bias within Euclid* on Astroparticle Symposium (143 participants )
- 2022 *Talk: Towards precision and accuracy in galaxy cluster simulations* on Cosmo’22 (153 participants)
- 2022 *Talk: Towards precision and accuracy in galaxy cluster simulations* during a 4 weeks visit to MIAPbP on the workshop “Advances in Cosmology through Numerical Simulations”
- 2020 Panoptic Cosmology with High-Redshift Surveys (canceled due to the COVID outbreak)
- 2020 3 weeks visit to MIAPbP during the workshop “The Accelerating Universe: The Physics and Astrophysics of Dark Energy and Gravitation” (canceled due to the COVID outbreak)
- 2020 2 months visit to the Institut Pascal during the programme “GOLD: The Golden Cosmological Surveys Decade” (canceled due to the COVID outbreak)

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### Media and Public Outreach:

The Letter by Castro et al. (2014) on the effects of gravitational lensing in supernovae data was discussed in the Pesquisa Fapesp journal (<https://revistapesquisa.fapesp.br/folheie-edicao-223/>)

### Editorial Services:

I serve as a referee for MNRAS and A&A.

## ■ Experience:

### Scientific Events:

Since 2019 I organize the scientific events for the galaxy clusters group of IFPU and OATs, including organizing the weekly journal club, seminars, and short courses. The group counts around 20 researchers, including students.

I have organized 14 scientific events: workshops as SOC and LOC (5), courses (2), debates (2), and outreach (5).

I have given approximately 30 (20 invited) presentations at institute seminars, workshops, and conferences.

### Academic Advisory:

2025 **Under-grad advisor**, Kevin Brugnera, Introduction to the analysis of hydro-simulations.  
Trieste University

2025 **Under-grad advisor**, Francesco Sulli, On the cosmological dependency of the halo mass sparsity.  
Trieste University

2024 **PostDoc supervisor**, Franklyn Aldas, On simulating proto-clusters.  
INAF-Astronomical Observatory of Trieste

2024 **Under-grad advisor**, Matteo Falasca, On machine learning and Bayesian methods for data analysis.  
Trieste University

Since 2023 **Ph.D. Co-advisor**, Marius Lepinzan, On PINOCCHIO development for next-generation surveys.  
Trieste University

2023 - 2024 **Under-grad Co-advisor**, Michele Calzavara, On the cosmology dependence of cluster profiles.  
Trieste University

Since 2022 **Ph.D. Co-advisor**, Tunç Tunker, Precise simulations for gravitational lensing.  
Federal University of Espirito Santo

2019 - 2023 **Ph.D. Co-advisor**, Alessandra Fumagalli, Precision cosmology with galaxy clusters: preparing for Euclid.  
Trieste University

2020 - 2022 **MSCA Fellowship supervisor**, Valerio Marra, I trained Dr. Marra on numerical cosmology as part of his MSCA fellowship: Cosmology BEyond HOMOgeneity and Isotropy.  
INAF-Astronomical Observatory of Trieste

2019 - 2021 **Master Co-advisor**, Giovanni Lacopo, On the effect of gravitational lensing on galaxy clustering observations.  
Trieste University

2018 - 2022 **Ph.D. Co-advisor**, Viviane Angélico Pereira Alfradique, Lensing Effects on Standard Sirens Analysis.  
Federal University of Rio de Janeiro

### Teaching:

2024 **Lecturer, Numerical Cosmology**, *University of Trieste*, Trieste, Italy.

As part of the course “Cosmology II” in the Master’s program in Physics, delivered 6 hours of lectures on Numerical Cosmology. This teaching activity was assigned through an open call as an “incarico di attività didattica integrativa”.

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- 2017 **Invited Short Course on Python for Cosmology**, Universidade Federal do Espírito Santo (UFES), Brazil.
- 2015 - 2016 **Temporary Professor of Physics**, FEDERAL UNIVERSITY OF RIO DE JANEIRO.  
Undergraduate courses: Physics I (2015-1), Physics II (2015-2).
- 2014 **Teaching Assistant**, FEDERAL UNIVERSITY OF RIO DE JANEIRO.  
Computational Methods of Theoretical Physics on C (2014-1), Experimental Physics I (2014-2).
- 2011 - 2012 **Teaching Assistant**, FEDERAL UNIVERSITY OF RIO DE JANEIRO.  
Computational Methods of Theoretical Physics on C (2011–2012).
- Thesis committee
- 2024 **Master thesis**, OSLO UNIVERSITY, Vetle Amundsen Vikenes, An Emulation-Based Model for the Full-Shape Projected Correlation Function.
- Outreach:
- Since 2022 **Scientific Guide**, ASTRONOMICAL OBSERVATORY OF TRIESTE.  
Guide exhibitions and night sky observations in the Margherita's Hack Observatory.