

# ELIOT AYACHE

POSTDOCTORAL RESEARCHER IN COMPUTATIONAL ASTROPHYSICS

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## PROFESSIONAL EXPERIENCE

**Postdoctoral researcher** ————— **Sept. 2021 - ...**  
OSKAR KLEIN CENTRE, STOCKHOLM UNIV. (SWEDEN)

### Lead of scientific research projects:

- Principal Investigator: Numerical simulations of gamma-ray burst relativistic jets with transverse structure.
  - o Designed the research project.
  - o Developed solutions for code stability in problematic regions of the parameter space.
  - o Was awarded the necessary computer time on National HPC resources.
- Development of original numerical PDE solvers. Implementation as an upgrade to an existing supernova modeling code.

### Machine Learning for literature exploration:

- Preliminary work in NLP to analyse consensus on scientific questions in the astrophysical literature. Experiments with document pooling, passage extraction and question answering using publicly available transformer models.

## EDUCATION

**Ph.D., Computational Astrophysics** ————— **2017 – 2021**  
UNIVERSITY OF BATH (UK)

Thesis: “Numerics and Theory of High-Energy Relativistic Astrophysical Transients”

### Numerical simulations:

- Developed from scratch a specialized massively parallel moving-mesh finite-volume relativistic hydrodynamics code in C++. This code allows accurate calculation of previously inaccessible regions of the parameter space and is now used by the community.
- Carried out HPC simulations on national facilities.
- 2 first-author publications in a top-level scientific journal.

### Machine learning:

- Carried out **unsupervised clustering** of astrophysical time-series data using **variational deep embedding and recurrent neural networks**.

### Scientific communication:

- Delivered talks and ML workshops at international conferences.
- Organized and chaired international conference sessions on machine learning.
- Wrote research proposals.
- Supervised multiple Bachelor and Masters theses.
- Teaching and outreach (~120h)

**M.Sc., Astronomy, Astrophysics and Space Engineering** ————— **2015 – 2017**  
OBSERVATOIRE DE PARIS, PSL RESEARCH UNIV. (FRANCE)

First of two years carried out in parallel with the last year of Mines ParisTech.

Relevant classes: data analysis, signal/image processing (building of a radio-telescope array imaging pipeline), numerical methods, Earth dynamics.

**Diplôme d'ingénieur (equiv M.Sc. Executive Engineering)** — **2013 – 2016**  
MINES PARISTECH, PSL RESEARCH UNIV. (FRANCE)

**Top 2 French scientific “Grande Ecole”** (National Graduate Engineering School). Applied mathematics and physics geared towards applications in the private sector. Major: Earth Science. **Relevant classes:** nuclear physics, geostatistics, signal processing, machine learning, cost assesement and modelling, economic calculus, climate dynamics.

**Preparatory classes, Physics and Chemistry** ————— **2011 – 2013**  
LYCÉE SAINT-LOUIS, PARIS (FRANCE)

Two-year intensive undergraduate program in mathematics, physics and chemistry.

**Ranked 79<sup>th</sup> / 3489** (National “Grandes Ecoles” admission competitive exam).

## PROFILE

I am an experienced numericist with a proven track record in harnessing complex algorithms for high-level applications in cutting-edge astrophysical research.

**I have an extensive experience in machine learning, data analysis and mathematical modeling.** Above all, I love learning in order to find new angles to solve the problems I’m tackling. I am excited to apply this mindset to new exciting projects

## KEY SKILLS

ML Algorithms | Data Visualization  
Statistical Modeling  
Clustering & Classification  
Numerical modeling  
Simulations | Model Development  
High-performance computing

## TECHNICAL SKILLS

**Languages:** Python (Expert), C/C++, Fortran, SQL, Bash, Java, HTML5/CSS.

**Packages and services:** Scikit-Learn, Tensorflow, PyTorch, Numpy, Pandas, OpenMP, MPI, HDF5, Git...

**Mathematical methods:** Neural networks, Bayesian statistics (MCMC), Gaussian processes, Numerical modeling (PDEs, finite-volumes, Monte-Carlo methods).

## LANGUAGES

- ♦ **French:** Native
- ♦ **English:** Fluent C2 (TOEFL iBT 112/120)
- ♦ **Spanish:** Intermediate B1
- ♦ **Swedish:** Beginner A2

## RESEARCH INTERNSHIPS

### Observatoire de Paris, LUTh (France)

Mar-jun 2017

#### Numerical modeling of the dynamics of stratified AGN jets.

- Implemented a radiation module into legacy numerical hydrodynamics code to compute spatially resolved radiative flux from relativistic jets. Investigated the nature of instabilities at the jet edges.

### Observatoire de Genève, Exoplanets Team (Switzerland)

May-Aug 2016

#### Characterization of the density and internal structure of low-mass exoplanets.

- Prediction of improvement in accuracy from observations with upcoming spectrographs on exoplanet internal structure inference using MCMC. Prediction of the number of ‘planets of interest’.

### NASA Jet Propulsion Laboratory (USA)

Jun-Sept 2015

#### Study of high-redshift galaxy clusters in preparation of the Euclid Mission.

- Investigated feasibility of a new method to confirm galaxy cluster candidates using the radial distribution of cluster members. Came up with innovative solutions to identify and reject cluster members using photometric redshift.

### Observatoire de Paris, GEPI (France)

Part-time - Sept-Feb 2014

#### Automatic estimation of galaxy morphology using convolutional neural networks for the EUCLID mission.

- Created synthetic EUCLID images dataset from HST images labelled with Galaxy Zoo.
- Used a **state-of-the-art CNN model** to investigate perspectives for automatic classification of galaxies in future EUCLID observations.

## AWARDS AND PROFESSIONAL GRANTS

- SNIC Medium allocation (Dardel), Sweden – Acting PI – **252,000 cpu-hrs** / 2022
- GW4-Isambard Tier-2 HPC Centre, UK – **40,000 node-hrs** / 2020
- Poster prize 3<sup>rd</sup> place, London Mathematical Society - Bath ML symposium / 2020

## SELECTED CONTRIBUTED TALKS AND WORKSHOPS

### Intl. Conf. on Machine Learning for Astrophysics – ML4Astro (Catania, Italy)

Jun. 2022

“An Unsupervised Dive into Gamma-ray Burst Afterglow Classification”

### European Astronomical Society annual meeting (remote)

Jul. 2021

Workshop: “Introduction to Machine Learning for Astrophysics” ([github repository](#))

Workshop: “Machine Learning Methods for Astrophysics”

### Royal Astronomical Society National Astronomy Meeting (remote)

Jun. 2020

(Canceled, re-selected and delivered 2021)

Same workshops as above

### Royal Astronomical Society specialist meeting: Radiation Hydrodynamics (London, UK)

Jan. 2021

“From Dynamics to radiation: Simulating GRB afterglow flares on a moving mesh”

### Yamada conference LXXI: GRBs in the gravitational wave era (Yokohama, Japan)

Nov. 2020

“Moving-mesh simulations of GRB afterglow flares”

## PUBLICATIONS

2 referred, incl. 2 first author, 2 non-referred (Proceedings), 1 in prep., ([Google Scholar](#))

- Ayache, E. H., Van Eerten, H. J., Daigne, F. (2020), [MNRAS, 495, 2979-2993](#), Late X-ray flares from the interaction of a reverse shock with a stratified ejecta in GRB afterglows: simulations on a moving mesh.
- Ayache, E. H., Van Eerten, H. J., Eardley, R. W. (2022), [MNRAS, 510, 1315-1330](#), GAMMA: a new method for modelling relativistic hydrodynamics and non-thermal emission on a moving mesh.
- Ayache, E. H., Laskar, T., (in prep.), Machine-learning insights into gamma-ray burst afterglow X-ray emission.