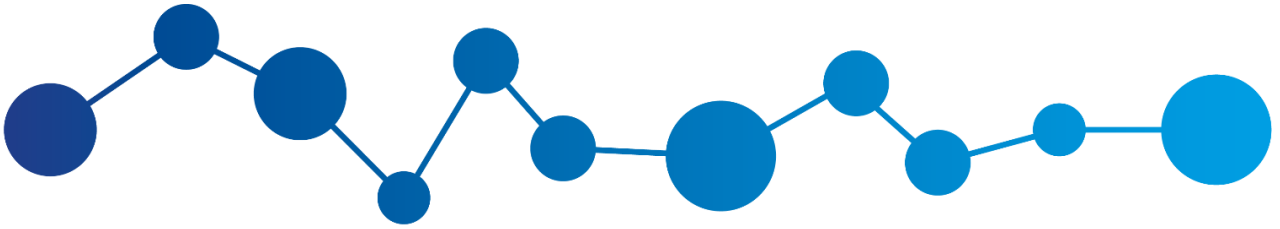**CALL FOR 10 PhD POSITIONS**

FUNDED WITH RESEARCH FELLOWSHIPS

41th CYCLE – A.Y. 2025/2026

MARIE SKŁODOWSKA-CURIE ACTIONS – COFUND DOCTORAL PROGRAMME

Opening of the call for applications: 20 December 2024

Deadline for the submission of applications: 10 March 2025

at 2 pm CEST (Italian time)

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Introduction

The "*FutureData4EU – Training Future Big Data Experts for Europe*" project is funded under the "*Marie Sklodowska-Curie Actions Co-funding of regional, national and international programmes – HORIZON-MSCA-2022-COFUND-01-01*" call of Horizon Europe – the Framework Programme for Research and Innovation. FutureData4EU is a 60-month project that involves the launch of a doctoral programme with PhD positions at the University of Bologna and at other Emilia-Romagna universities acting as *Implementing Partners*, i.e. the Universities of Ferrara, of Modena and Reggio Emilia, of Parma, the Piacenza Campus of the Politecnico di Milano, and the Piacenza Campus of Università Cattolica del Sacro Cuore.

FutureData4EU aims to offer early stage researchers, i.e., not already in possession of a doctoral degree, an innovative training programme with a strongly international, inter-sectoral and inter-disciplinary approach, through transnational mobility and career development. FutureData4EU is open to researchers from all over the world. The project seeks to strengthen cooperation with the non-academic world, enabling young PhD students to develop their professional skills within local, regional and/or national socioeconomic ecosystems in the area of Big Data.

Big Data management, including through high-performance computing, is in fact regarded as the richness of the new knowledge economy. It provides unprecedented research and innovation opportunities across a number of applicative domains, from climate and geophysical simulations to health, from mobility and logistics to cultural heritage and multimedia, from digital change in production systems to new materials and financial analysis. Digital infrastructures, high-performance computing architecture, large-scale cluster architecture and ultra-wideband networks will experience significant innovation in the upcoming years.

70% of the Italian computing and storage capacity is currently located in Emilia-Romagna, thanks to the supercomputing facilities at CINECA (one of the European Large-Scale Facilities and founder of PRACE – Partnership for Advanced Computing in Europe), INFN (National Institute for Nuclear Physics), and the Leonardo supercomputer supported by the EuroHPC Joint Undertaking. CINECA and INFN are partners in the project, alongside Regione Emilia-Romagna, to create a lively research and innovation ecosystem, making Emilia-Romagna an authentic data valley and the ideal location to gain knowledge and skills in this domain.

This call for applications is published on the FutureData4EU website (https://site.unibo.it/futuredata4eu/en). Any additions, amendments or updates will also be published on the website. This announcement of selection is an official announcement to all intents and purposes.

Art. 1. Programme description

1.1.   Goals

The FutureData4EU PhD programme will train a new generation of researchers with inter-disciplinary and transferable skills, supporting their career and providing them with the knowledge necessary to work with academic and business organisations, thanks to a large network of Associated Partners involved in the project, from highly reputed businesses to high-level national and international research centres and infrastructures in the field of Big Data.

The programme innovatively combines training, research and development of transferable skills in the area of Big Data.

International talents will have the opportunity to learn by developing research and innovation projects across a wide range of thematic areas relevant to Big Data – health, culture, security, industry, aerospace, climate, energy, agriculture and environment.

1.2.   Programme

FutureData4EU involves the activation of 53 PhD positions within 47 PhD programmes across the six Emilia-Romagna universities, covering 6 thematic areas: Health; Culture, Creativity and Inclusive Society; Civil Security for Society; Digital, Industry and Space; Climate, Energy and Mobility; Agriculture and Environment; Enabling Technologies.

The first announcement was published in June 2024, resulting in the selection of 43 candidates out of 53 available PhD positions. This announcement of selection offers candidates from all over the world a total of 10 PhD positions in just as many PhD programmes, for a duration of 36 months each, in the following thematic areas relevant to Big Data (Annex 1 – FutureData4EU doctoral positions and research themes):

1.   Culture, Creativity and Inclusive Society;
2.   Civil Security for Society;
3.   Digital, Industry and Space;
4.   Climate, Energy and Mobility;
5.   Enabling Technologies

Each candidate will choose 1 thematic area, indicating – for information purposes only – their order of preference for each PhD position available in that area (Annex 1 – FutureData4EU doctoral positions and research themes). In order to assign available the PhD positions, the selection committee (Art. 5 Evaluation Committee), at its sole discretion, will assess each candidate's suitability for one or more positions. In case of manifest or tacit withdrawal of a successful candidate, the position will be offered to the next suitable candidate on the ranking list (Art. 6 Ranking lists).

The training provided within the FutureData4EU project consists of three dimensions:

1. The first dimension of training concerns the disciplinary and multi-disciplinary domains of the research projects and the development of specific knowledge, methods and skills by attending courses, seminars and workshops.

2. The second dimension of training refers to transferable skills, including the ability to write and present scientific articles and reports at seminars, workshops and conferences; how to manage research data and open science; how to file a patent application and manage intellectual property; fundamentals of technology transfer and entrepreneurship; how to do scouting for research funds and how to prepare successful applications for funding. Transferable skills training will be provided both locally and during international and/or intersectoral secondments.
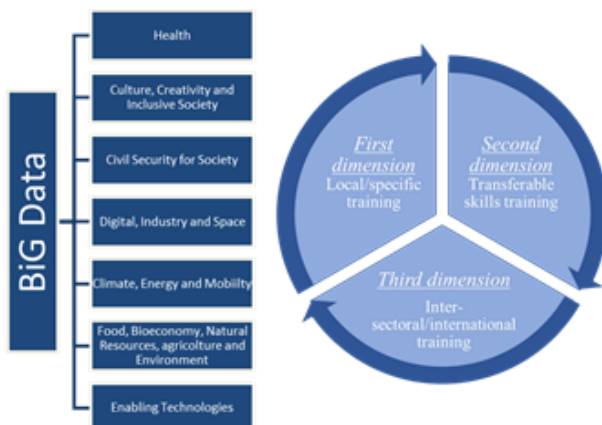
3. The third dimension of training covers international/inter-sectoral secondments. two secondments will be arranged – one at an international academic institution and one at a non-academic organisation – fostering inter-sectoral mobility.

Art. 2. Admission requirements

On the deadline for applications, all candidates of every nationality must meet the following requirements, failing which they will be excluded:

✓ **Mobility**. Candidates must not have resided or carried out their main activity (work, studies, etc.) in Italy for more than 12 months in the 3 years immediately before the deadline of this call for applications, i.e., from March 11th, 2022, until March 10th, 2025. Compulsory national service and time spent as part of a procedure for obtaining refugee status under the Geneva Convention are not considered.

✓ **Qualifications**. Candidates must be in possession of a second-cycle academic qualification (e.g., two-year master's degree, degree of the previous degree programme system, equivalent Advanced Artistic and Musical Training – AFAM qualification).

Foreign qualifications must be recognised as equivalent to a second-cycle academic qualification and give access to PhD studies in the country of issuance.

Candidates who, on the deadline for the submission of applications, do not meet the aforementioned requirements will be admitted conditionally, but must obtain a qualification that gives access to PhD studies and have it certified no later than 26th May, 2025. For the sake of clarity, 26th May, 2025 is the final deadline to submit the proof of achievement of the qualification that gives access to PhD studies via cofund@unibo.it, failing which the candidate will not be admitted.

Candidates who apply based on a qualification they obtained in a foreign (European Union/non-European Union) country without a document certifying its authenticity and equivalence to a second-cycle academic qualification (e.g., Diploma Supplement, *Dichiarazione di Valore*/Declaration of Value issued by the Italian diplomatic authority in the country where the qualification was obtained, proof of authenticity and comparability issued by organisations such as ENIC-NARIC), but in any case they must submit the aforementioned document, which is necessary for the declaration of authenticity and equivalence of the second-level degree obtained, by 15th September, 2025, otherwise they will be excluded from the selection procedure.

✓ *Doctoral Candidate stage*. Candidates must not be already in possession of a doctoral degree.

The following candidates will not be admitted to the selection procedure:

- candidates who hold a tenured position at a university or institution referred to in Article 22, paragraph 1 of Law No. 240 of December 30, 2010 (hereinafter L. 240/2010);
- candidates who have a degree of kinship or affinity up to and including the fourth degree with a teacher of the department or organisational structure that offers the position and related contract, or with the Rector, the Director General or a member of the Board of Governors of the University

- candidates who had a Italian contract "*assegno di ricerca*" (research fellow) or Ricercatore a Tempo Determinato (fixed-term assistant professor) according to Articles 22 and 24 of Law 240/2010 with the University of Bologna or another state, non-state or virtual university, in Italy or abroad, or with an institution referred to in Article 22, paragraph 1 of Law 240/2010, for a total period that, when added to the duration of the contract for which they are applying for, exceeds 12 years, including on a non-continuous basis. Periods on maternity/paternity or long-term medical leave in accordance with the legislation in force are not taken into account when calculating the abovementioned duration.

Art. 3. Application

3.1. Application procedure

Applications may only be submitted through the dedicated procedure available at https://studenti.unibo.it (online platform Studenti Online).

The application deadline is March 10th, 2025, at 2:00 PM (CEST, Italian time).

In order to be accepted, the application must be:

- Sent before the deadline via the online submission procedure by accessing at Studenti Online. All annexes must be uploaded in pdf format.
- Accompanied by all the required documentation (3.2 Documents to be attached to the application).

Failing to meet any of the requirements of Art. 2 Admission requirements will result in the exclusion of the candidate, at any time during the selection procedure or upon signing the contract.

Applications submitted in any way other than the above will not be considered.

This selection announcement, its annexes and all documents relevant to the application are available on the FutureData4EU website (https://site.unibo.it/futuredata4eu/en).

3.2. Documents to be attached to the application

Candidates will be required to attach the following documents to their online application:

	DOCUMENTS REQUIRED	DESCRIPTION
a)	**Valid photo ID document**	Scanned image of both sides.
b)	**Proof of achievement of each second-cycle academic qualification obtained**, detailing: 1. University that issued the qualification 2. Type of degree (two-year master's degree, single-cycle degree, degree of the previous degree programme system, etc.) 3. Name of degree programme 4. Degree programme class (only for Italian qualifications) 5. Date of qualification 6. Final grade 7. List of exams and marks, indicating the number of University credits (CFU), if in use within the university system that issued the qualification. *For candidates who, on the application date, have not obtained their second-cycle academic qualification yet:* **Transcript of records of the second-cycle academic qualification**, together with a list of exams and marks (in English).	Type of proof, for candidates who graduated from: • **1. Italian state universities**: • Dated and signed self-certification of master's degree or degree of the previous degree programme system; • **2. EU or non-EU universities**: • Original second-cycle degree certificate stating the date of qualification and final grade; • Transcript of records of the second-cycle academic qualification, together with a list of exams and marks (in English); • If already available, document to certify the equivalence of the qualification (e.g. Diploma Supplement, *Dichiarazione di Valore*/Declaration of Value issued by the Italian diplomatic authority in the country where the qualification was obtained, proof of authenticity and comparability issued by organisations such as ENIC-NARIC) (in English). Please note that the aforesaid document must be submitted no later than 15th September, 2025, failing which the candidate will not be admitted. • **3. Italian private universities**: As an alternative to the certificate, a self-certification complete with all required information or the Diploma Supplement

		may be attached. Type of proof, for candidates who have not obtained their second-cycle academic qualification yet: • Transcript of records of the second-cycle academic qualification, together with a list of exams and marks (in English).
c)	**Document stating the selected thematic area and the order of preference for each available PhD position within the area.**	Pdf document generated through the Form On Line (FOL) system, available at https://fol.unibo.it/futuredata4eu.
d)	**Curriculum Vitae in English**	Please use the CV template available on the project website.
e)	**Research project**	To be drafted: - in English; - using the template available on the FutureData4EU website (https://site.unibo.it/futuredata4eu/en); - maximum length of three (3) pages excluding charts and images (pages in excess will be discarded). The research project must include: project title; research theme selected from among those available; project idea, goals, proposed research methodology; relevance of the project to the candidate's competencies, also in relation to the position for which the application is submitted.
f)	**Max. 3 reference letters in English**	Reference letters will be subject to evaluation.
g)	**Other relevant documents**	Additional documents that the candidate deems useful for the evaluation, in relation to the available positions (Annex 1 – FutureData4EU doctoral positions and research themes).

h)	*For candidates who wish to request adaptations to be made for the entrance test* **Request for adaptation form and required medical certificate**	For further information on the adaptations and documentation to be attached, see the section 4.3 Candidates with disabilities or specific learning disorders (SLD) of this call.

Art. 4. Selection process

4.1. Selection steps

The indicative timetable for the selection process is presented below.
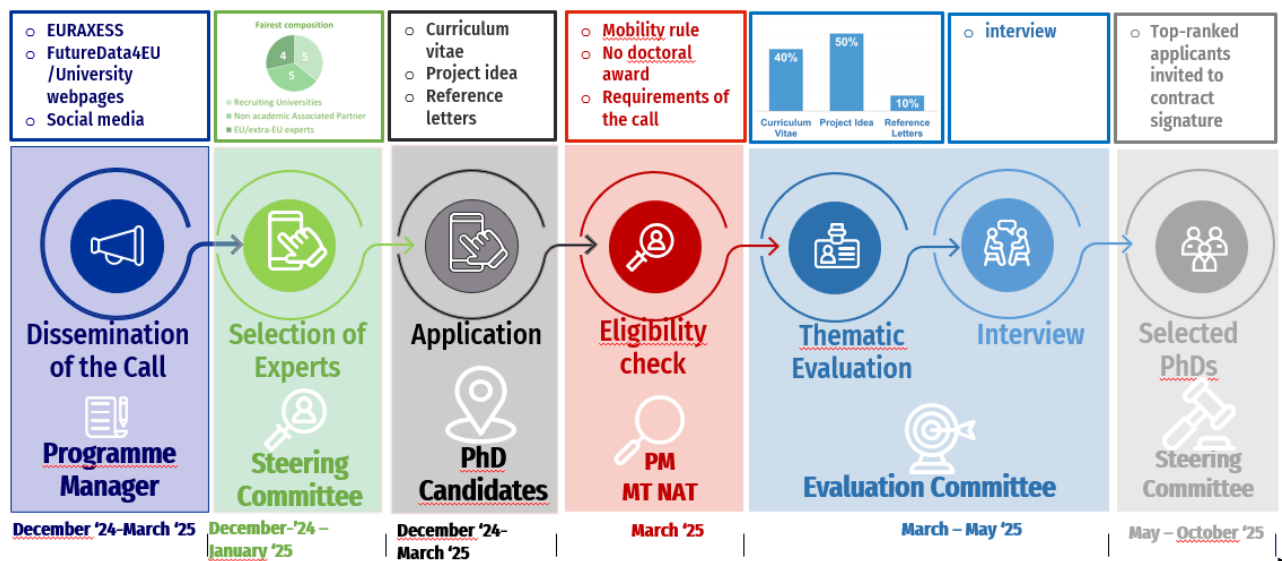
Any delays in or notices concerning the overall process will be published on the FutureData4EU website (https://site.unibo.it/futuredata4eu/en).

Consistently with the principles and requirements of the European Charter for Researchers, the Code of Conduct for the Recruitment of Researchers and the Human Resources Strategy for Researchers – HRS4R, the selection process will respect the principles of fairness and equality, avoiding any form of discrimination based on gender, age, ethnicity, national or social origin, religion or belief, sexual orientation, language, disability, political opinion, social or economic status or nationality, in accordance with the principles expressed by all involved recruiting universities.

The entire selection process consists of four steps. The results for each step will be anonymised and published on the FutureData4EU website as soon as the process is completed. The candidates will be informed of the

publication of the results by email from cofund@unibo.it exclusively to their University email address name.surname@studio.unibo.it, assigned upon registering on the Studenti Online website, before filling out the application.

- ✓ **STEP 1) Eligibility check**. The eligibility check will be performed by the Programme Manager (PM) together with the Project Management Team (MT) and the Network Administrative Team (NAT). Candidates may be asked to provide further clarifications or to integrate provided documents at this stage, through the institutional email address nome.cognome@studio.unibo.it assigned to each candidate. The results of this phase will be published starting from 20th March 2025.

- ✓ **STEP 2) Document evaluation**. An Evaluation Committee will be set up, comprised of six Panels, one for each thematic area. Each Panel will be made up of 14 panellists (Art. 5 Evaluation Committee). Initially, each panellist will evaluate the applications independently and remotely, assigning a score to each candidate according to specific criteria (4.4 Evaluation criteria). The Panel will then meet in person or online to discuss each evaluation and reach a unanimous score.

  For each thematic area, based on the assigned score assigned, a shortlist of the candidates admitted to Step 3 will be prepared, anonymised and published on the FutureData4EU website, starting from 31th March, 2025. Candidates admitted to Step 3 will be invited to an interview through the aforementioned institutional University email address, while those who did not pass to the interview will be informed of the outcome of Step 2. The interviews will be scheduled starting from 1st April, 2025.

- ✓ **STEP 3) Interview**. All interviews will be conducted by the single Panels in English and remotely via the Microsoft Teams platform. Each interview will last approximately 30 minutes. At the beginning of the interview, each candidate must present the original identification document attached to the admission application. Each candidate will be assigned a score according to the specified evaluation criteria (4.4 Evaluation criteria) and a suitability evaluation for one or more advertised position, at the sole discretion of the Panel. The results of Phase 3 will be anonymously published on the FutureData4EU website (https://site.unibo.it/futuredata4eu/en) starting from 30th April 2025. Notification of the publication will be sent to the involved candidates through the institutional email address.

- ✓ **STEP 4) Final decision and ranking list**. The Evaluation Committee, in agreement with the NAT, will prepare a final ranking list for each thematic area based on the score for Steps 2 and 3, indicating the

suitability status assigned after Step 3 and proposing the assignment of winners to individual positions. The six final ranking lists will be subject to approval by the FutureData4EU Steering Committee. The final rankings will be anonymously published on the FutureData4EU website (https://site.unibo.it/futuredata4eu/en) starting from 15th May, 2025 Notification of the publication will be sent to the involved candidates through the aforementioned institutional email address. Candidates who have been assigned a position will be informed via the institutional email address about the subsequent steps related to contracting and enrollment, managed by the respective universities of the region. In case of withdrawal, the position will be assigned in order of ranking to the next eligible candidate for the same position (Art. 6 Ranking lists).

4.2.   Redress procedure

After publication of the final ranking lists, candidates may file a judicial appeal (within 60 days) or an extraordinary appeal (within 120 days), as provided for by the regulations in force, if they believe that there have been irregularities in the evaluation process that have affected the final decision. Redresses may only concern procedural aspects and/or clerical errors, but not the evaluating experts' opinion on the quality of an application.

4.3.   Candidates with disabilities or specific learning disorders (SLD)

Candidates who wish to request adaptations to be made for the entrance test must do so by the deadline for the submission of applications.

Please note that, since the evaluation only concerns the requirements to apply, and no written test is foreseen, but only an oral interview, the request may only be submitted if adaptations are necessary for the interview (Step 3).

Adaptations may comprise:

- Additional time for the candidate to think and organise their answers;
- Questions in writing during the interview for candidates with hearing disabilities;
- Other adaptations depending on the specific certified difficulties or needs related to the candidate's health (please specify the adaptations required).

The list of available adaptations is included in the Request for adaptation form, as specified below. If the adaptation requested cannot be guaranteed for organisational reasons and/or due to mandatory instructions, an alternative, equivalent measure will be implemented.

The procedure for requesting adaptations is as follows:

- Access *Studenti Online* and go to the application for selection;
- Download the Request for adaptation form (available in .pdf format);
- Fill in and upload, in the appropriate section, the Request for adaptation form (in .pdf format);
- Upload the necessary specialist documentation in the appropriate section, as specifically requested in the Request for adaptation form (in .pdf format).

Please do not upload any unrelated documentation to this section.

Candidates with disabilities or SLD residing in foreign countries who intend to request adaptations must submit a legalised (or apostilled, where provided) certification confirming their disability or SLD, issued in their country of residence and accompanied by an official translation into Italian or English.

The specialist documentation will be examined by the competent offices to make sure that it certifies a disability or specific learning disorder recognised by the legislation of Italy or the candidate's country of residence.

The documentation will be examined by the Service for Students with Disabilities and SLD to make sure that the request for adaptations is consistent with the documentation submitted. If the documentation is incomplete or hard to read, supplementary details will be requested, via the University email account name.surname@studio.unibo.it, which must be submitted by the final deadlines specified in the message.

It will not be possible to make the adaptations requested by candidates who fail to submit their request by the deadline above or fail to send the required supplementary documentation by the deadline indicated by the Service for Students with Disabilities and SLD.

Any adaptations granted will be notified via e-mail from cofund@unibo.it to the University email address name.surname@studio.unibo.it.

Clarifications strictly concerning the procedures for requesting adaptations may be obtained by contacting the Service for Students with Disabilities and SLD via email to ases.adattamentiammissione@unibo.it.

4.4. Evaluation criteria

Applications will be evaluated based on the following criteria.

STEP 1: Eligibility check, carried out by the NAT		
Eligibility threshold: both criteria must be met. Each criterion will receive a positive/negative evaluation (pass/fail).		
Eligibility of candidates	Compliance with admission requirements (Art. 2 Admission requirements)	PASS/FAIL
Eligibility of applications	Compliance with application procedures (Art. 3 Application).	PASS/FAIL
STEP 2: Document evaluation, carried out by the Evaluation Committee *In Step 2, each candidate will receive a score 0-100.* *Threshold for admission to Step 3:* 70/100. Justified career interruptions (e.g. maternity/paternity leave, military service) will not be penalised.		
CV evaluation (score 0-40)	*The use of the FutureData4EU CV template is recommended.* The following aspects will be taken in consideration: University education, English proficiency, experience and achievements (e.g. research experience, awards/recognitions, international mobility experience), contribution to intellectual property (e.g. registered patents), work experience, relevance to the selected thematic area.	max. 40 points
Research project evaluation (score 0-50)	*The use of the FutureData4EU model is mandatory.* The following aspects will be taken in consideration: significance and relevance of the research project idea to the selected	max. 50 points

	thematic area and available PhD positions, clarity in the description of the objectives, validity of the proposed methodology, coherence of the competencies declared with the research project idea.	
Reference letter evaluation (score 0-10)	The relevance and appropriateness of the submitted letters of reference will be evaluated.	max. 10 points
STEP 3: Interview conducted by the Evaluation Committee *In Step 3, each candidate will receive a score 0-100.* *Threshold for admission to Step 4:* 70/100 All interviews will be conducted online via Microsoft Teams in English.		
Excellence of the candidate and suitability for the positions available (score 0-100)	Soundness of the candidate's cultural and scientific background, ability to argue their research project, motivation and personal career prospects will be evaluated.	max. 100 points
STEP 4: Final ranking list prepared by the Evaluation Committee The final ranking list will be prepared by adding together the scores for Steps 2 and 3 and will include a list of candidates who scored at least 140/200. The ranking list will also indicate each candidate's suitability status with respect to the available positions.		

Art. 5. Evaluation Committee

5.1. Evaluation Committee and Panels

An Evaluation Committee will be set up, made up of six Panels. Each Panel will be comprised of at least 14 panellists, selected to ensure:

- Fair balance between internal and external panellists: 5 to 7 experts will come from the Emilia-Romagna universities involved in the FutureData4EU programme;

- European dimension: 4 to 5 experts will be based in a country other than Italy;

- Intersectoral presence: 3 to 4 experts will be selected from among the FutureData4EU non-academic associated partners.

Each candidate will be evaluated by at least 7 members: 3 panellists from the host universities, 2 international experts and 2 panellists from the non-academic associated partners. Subject to the availability of the panellists, an attempt will be made to ensure a gender balance.

5.2. Appointment of the experts: confidentiality and no conflict of interest

All expert evaluators involved in the evaluation process will be required to sign a confidentiality agreement regarding information and documents. The experts will also have to guarantee the absence of any conflict of interest.

Art. 6. Ranking lists

The final ranking list for each thematic area will be prepared by the Evaluation Committee (5.1 Evaluation Committee and Panels) by adding together the scores for Steps 2 and 3.

In the event that two or more candidates obtain the same score, the ranking order will be determined by considering, in this order:

- Whether the candidate is a beneficiary of international protection (with refugee or subsidiary protection status);
- The least represented gender among the successful candidates in the thematic area, without taking withdrawals into account;
- Which candidate is the youngest.

At its sole discretion, the Evaluation Committee will give an opinion on each candidate's suitability for the PhD positions available. Each candidate may be suitable for one or more positions.

Each position will be assigned at the sole discretion of the Evaluation Committee to a candidate suitable for that position on the merit ranking list, based on the score obtained and on the candidate's suitability status for the position in question.

Each successful candidate will be admitted to the corresponding PhD programme at the university that offered the position and will be asked to sign the research fellowship contract (*Assegno di ricerca*) effective from 1st November, 2025.

It will be possible to proceed down the ranking list due to the following:

- manifest withdrawal from the position through an email sent from the institutional email address (nome.cognome@studio.unibo.it) generated at the time of submitting the admission application to the address cofund@unibo.it;
- tacit withdrawal from the position, by not confirming acceptance of the position within the specified deadlines, not signing the contract, or not enrolling in the doctoral programme;
- failure to submit the necessary documentation for contracting and enrolment within the specified deadlines.

In such cases, the vacant position will be offered to the next eligible candidate in the ranking list for that specific thematic area.

Please note that September 15th, 2025 is the final deadline for submitting the documentation referred to in Article 3.2 Documents to be attached to the application, failing which the application will be excluded from the selection procedure. This deadline may be extended only and exclusively in exceptional, duly justified cases, following evaluation and approval by the Restricted Steering Committee.

It will not be possible to proceed down in the ranking list beyond July 31st, 2025.

Art. 7. Contract signature and enrollment

Successful candidates will be offered a contract for *Assegno di ricerca* and be enrolled in the PhD programme at the recruiting university, according to the specific indications and deadlines that will be communicated.

Art. 8. Contract and salary

8.1. Contract and working conditions

The university involved in FutureData4EU as an Implementing Partner who offered the position will enter into a three-year (36-month) employment contract with the corresponding successful candidate. The contract will be in the form of a Research Fellowship (*Assegno di ricerca* pursuant to Art. 22 of L. 240/2010), to be signed by the successful candidate and the Head of the hosting Department. It will specify the working conditions of the PhD student, their obligations under FutureData4EU and the regulations in force at the host university. By signing the contract, strictly no later than 31 October 2025, the candidate commits exclusively and full time to the programme.

The Research Fellowship is exempt from tax, but includes compulsory social security contributions (pension, work accident insurance, sickness, maternity/paternity, adoption and foster care leave).

During periods of absence due to leave or accident as mentioned above, subject to appropriate notification by the research fellow, the activity covered by the research fellowship will be suspended. The employment relationship will continue for the remaining period, resuming when the cause of suspension ends.

During periods of mandatory maternity/paternity leave, the allowance paid by INPS will be supplemented up to the full amount of the research fellow, as divided into the appropriate number of monthly instalments.

The contract may also be suspended in the event of parental leave, sickness or other extended periods of absence that make it objectively impossible to carry out the activities. In such cases of suspension, the contract will be extended for the duration of the suspension.

8.2. Salary

The annual salary paid to researchers is of €27,238.83 (gross salary excluding employer's contributions to tax and social security). This annual amount consists of a living allowance and a mobility allowance, which covers mobility expenses (e.g. relocation, travel expenses).

Researchers with dependents at the time of recruitment, or who acquire dependents at any time during the course of the project, will be entitled to a family allowance. This is reserved for those who (i) are married or (ii) are in a relationship equivalent to marriage recognised by the law of the country in which that relationship was formalised, or (iii) have dependent children who are effectively supported by the candidate.

The research project carried out by the candidate will receive financial support for research, training and networking costs, which can be used to purchase research materials and equipment and cover publication costs, travel expenses (e.g. to attend conferences/training courses, networking activities) and external services. Funding will be managed by the host Department and subject to the Supervisor's approval.

Art. 9. Start of the doctoral programmes and tuition fees

Successful candidates will enrol in the FutureData4EU PhD programmes starting in the 2025/2026 academic year. The FutureData4EU PhD programme will start on 1st November, 2025.

FutureData4EU doctoral students are exempt from paying any tuition fees for doctoral programmes. However, they are required to cover registration fees, which include the regional tax for the right to education, stamp duty, and insurance. These fees will be subsequently reimbursed.

Art. 10. Obligations of FutureData4EU PhD students

10.1. Activities of FutureData4EU PhD students

The FutureData4EU PhD students are required to carry out the research project that will be assigned to them, which will not necessarily be the one they submitted upon applying for the PhD position. The research project to be carried out during the PhD programme will be approved by the Academic Board of the PhD programme in which they will be duly enrolled. The research project will be part of the researcher's career development plan, to be agreed with the Supervisor together with the planned training activities. Each year, following the assessment of the activity carried out by the FutureData4EU PhD student, the competent Academic Board of the PhD programme will decide whether to admit the FutureData4EU PhD student to the following year. By reasoned decision, the competent body may recommend that the PhD student be excluded from the programme.

10.2. Secondments

In order to ensure that the FutureData4EU PhD students receive the most innovative and cutting-edge training and fully benefit from the opportunities offered to them, 2 secondments are recommended: one of 6-8 months at an academic institution in Europe, and one of 4-6 months at a non-academic (inter-sectoral) organisation. The total duration of secondments may not exceed 12 months.

10.3. Publications

All scientific publications resulting from research funded under this call must be open access. Furthermore, in all publications and dissemination material (e.g. posters presented at conferences), the FutureData4EU PhD students must mention the funding programme by including the European Union flag followed by the wording: "*Co-funded by the European Union*" and the disclaimer: "*Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the*

European Union or Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them".

Art. 11. Award of the qualification

The award of the PhD degree is subject to full compliance with the regulations for PhD programmes, in force at the respective host universities.

The final exam will consist in the discussion of the candidate's thesis.

Art. 12. Ownership of results and confidentiality

The intellectual and industrial property rights over any results achieved by the PhD student, including but not limited to software, industrial inventions (patentable or otherwise), know-how, models, data and data collections, are governed in accordance with the law in force, the recruiting university's regulations, and any agreements executed with other universities, firms or institutions involved.

The FutureData4EU PhD students must promptly inform their Supervisor of any results achieved and agree not to disclose or use them without the authorisation of the recruiting university.

The FutureData4EU PhD students are also required to sign a confidentiality and intellectual property right acknowledgement agreement in relation to any confidential information, data and documents that may come to their attention in the course of their activity at and/or on behalf of the recruiting university.

In any case, the PhD students are permitted to undertake standard publication activities foreseen in their training programme, although this must be scheduled in a manner that allows protection of research results.

Art. 13. Ethical principles

Research and innovation activities must comply with national, international and EU ethical principles and standards. Special attention must be paid to the principle of proportionality, the right to privacy, the right to personal data protection, the right to a person's physical and mental integrity, the right to non-discrimination and the need to ensure high levels of protection of human health. Research and innovation activities must focus on civil applications only.

Art. 14. Processing of personal data

Pursuant to Article 13 of Regulation (EU) 2016/679, the personal data provided by the candidates in the application or however obtained for that purpose by the universities will be processed for the purpose of conducting the selection and managing any related activities and tasks. The data will be processed by the persons responsible for the selection, including the Evaluation Committee, in the manner, with the timing and to the extent required to achieve the aforementioned purposes, including disclosure to third parties for the purposes specified in this call, if needed. The legal basis for the data processing is Article 6, paragraphs 1(c) (processing for compliance with a legal obligation) and 1(e) (processing for the performance of a task carried out in the public interest) and Article 9, paragraph 2(g) (processing for reasons of substantial public interest) of Regulation (EU) 2016/679.

The joint controllers for the purposes of this evaluation and selection of PhD candidates are:

- Alma Mater Studiorum – Università di Bologna (registered office: via Zamboni 33, 40126 – Bologna, Italy). The Data Protection Officer's contact email: dpo@unibo.it; certified email: scriviunibo@pec.unibo.it;

- Università di Ferrara (registered office: via Ludovico Ariosto 35, 44121 – Ferrara, Italy. The Data Protection Officer's contact email: privacy@unife.it; dpo-team@lepida.it; certified email: ateneo@pec.unife.it);

- Università degli studi di Modena e Reggio Emilia (registered office: via Università 4, 41121 – Modena, Italy; The Data Protection Officer's contact email: dpo@unimore.it; certified email: dpo@pec.unimore.it;

- Università di Parma (registered office: via Università 12, 43121 – Parma, Italy; The Data Protection Officer's contact email: dpo@unipr.it; certified email: dpo@pec.unipr.it);

Each university, acting as an independent controller for the subsequent steps of the selection process, will store and use any personal data and contact details provided by the PhD students also after completion of the selection procedures for operational, administrative, accounting and/or other purposes in connection with the management of institutional and project-related activities as well in order to comply with the law, as well as to notify them of any opportunities (scholarships, awards, etc.).

The personal data for the subsequent contract signing and enrolment procedures will be collected and processed by each university as an independent controller, in accordance with the aforementioned regulations and in compliance with the privacy policy statement available on the institutional website of each

university. They may be shared with Alma Mater Studiorum - University of Bologna for project-related reporting and auditing purposes.

In any case, the provision of personal data is essential in order to participate in the selection and for the subsequent contract signing and enrolment procedures. Failure to provide such data will make it impossible to participate in the selection process and be admitted to the PhD programmes.

The candidates have the right to access the personal data they have provided to participate in the competitive selection and for contract signing and enrolment purposes, to request and obtain the rectification, erasure or restriction on processing, as well as to object to the processing of their data by sending a request to the competent offices of the recruiting university.

Data subjects who believe that their personal data have been processed in violation of the requirements of the aforementioned EU Regulation may file a complaint with the Data Protection Authority or with the competent court.

Art. 15.   Final provisions

For anything not provided for in this call, please refer to the Regulations governing PhD programmes of the recruiting universities, to Ministerial Decrees 226/2021 and 301/2022, to Article 22 of Law 240/2010, as amended, and to the relevant provisions of the recruiting universities.

By submitting an application to participate in the selection procedures the candidate accepts the rules contained in this call and in the Regulations governing PhD programmes, the Regulations governing research fellowships and the regulations pertaining to the FutureData4EU project.

The FutureData4EU boards have the right to verify the accuracy of the declarations in lieu of certifications or affidavits submitted by the candidates and pursuant to Presidential Decree 445/2000 at every stage of the procedure. Should the above-mentioned check reveal that the declarations are inaccurate, the declarant will lose any benefits arising from any decision issued on the basis of an inaccurate declaration, without prejudice to the provisions of Article 76 of Presidential Decree 445/2000 on sanctions pursuant to the Italian Criminal Code and related special laws.

The responsible person for the procedure is Dr. Verdiana Bandini, Head of the Research Division (ARIC) at Alma Mater Studiorum - University of Bologna.

For clarifications or further information about this call, please contact cofund@unibo.it.

This call has been translated into English solely for informational purposes; only the Italian version will be valid for all legal purpose.

Annex 1 – FutureData4EU doctoral positions and research themes

List of positions

Thematic Area 1 – Health

UNIVERSITÀ DI BOLOGNA (UNIBO)

Enhancing Dermatologic Interventions through Big Data-Driven Understanding

of Placebo Effects

Doctoral Position

Enhancing Dermatologic Interventions through Big Data-Driven Understanding of Placebo Effects

Doctoral Programme

Surgical Sciences and Innovative Technologies

Description of the doctoral position's main topic

The doctoral research within the COFUND research project 'Futuredata4EU' will focus on advancing our understanding of placebo and nocebo effects in dermatology, as outlined in the project's overarching aim. This research topic holds significant relevance due to its potential to revolutionise dermatologic treatment strategies and enhance patient outcomes.

At the regional level, the project aims to collaborate with dermatology clinics and research centres to collect diverse datasets encompassing patient demographics, clinical profiles, and treatment outcomes. The project's findings will contribute to addressing critical gaps in psycho-neuro-biological research within dermatology, aligning with national priorities for advancing healthcare innovation and personalized medicine. By leveraging big data analytics and machine learning techniques, the research will pave the way for novel therapeutic approaches tailored to individual patient characteristics and expectations, thus enhancing the effectiveness and sustainability of dermatologic treatments nationwide. The project will engage with national and international leading experts in placebo and nocebo, dermatology, neuroscience, and data science. This international collaboration will facilitate the data collections and the dissemination of research findings, establishment of best practices, and potential harmonization of clinical trial designs across borders, ultimately benefiting patients worldwide. Moreover, participation in this doctoral research offers candidates a unique opportunity to delve into cutting edge interdisciplinary research at the intersection of psychology, dermatology, neurobiology, and data science. The project's emphasis on creativity,

independence, and innovation aligns with the career aspirations of aspiring researchers, providing a solid foundation for future career advancement in academia, industry, or clinical practice.

Candidates embarking on this doctoral research journey will have the chance to develop their own project ideas within the broader research topic of placebo and nocebo effects in dermatology. This opportunity fosters creativity and critical thinking, empowering candidates to shape their research trajectory and contribute novel insights to the field. Furthermore, the interdisciplinary nature of the research opens doors to diverse career pathways, including academia, healthcare management, pharmaceutical research, and data science, thereby enhancing the candidates' employability and professional growth prospects.

In summary, the doctoral research within the COFUND project 'Futuredata4EU' offers a dynamic and intellectually stimulating environment for candidates to explore the intricate relationship between patient expectations, treatment outcomes, and neurobiological mechanisms in dermatology. With its regional, national, and international implications, this research topic promises to catalyse innovation in dermatologic care and provide candidates with valuable skills and opportunities for future career development.

Sub-themes of the doctoral position's main topic (if any)

None

Potential Supervisors

Katia Mattarozzi, Bianca Maria Piraccini, Gastone Castellani, Emanuela Marcelli, Arianna Bagnis, Andrea Evers.

Doctoral candidate's desirable skills and competences

Scientific and technical skills

Expertise in placebo and nocebo effects, with a strong understanding of neurobiological mechanisms underlying these phenomena.

Proficiency in dermatology, including knowledge of dermatologic conditions, treatment modalities, and patient care.

Demonstrated research experience in related fields, preferably with a focus on psychosocial aspects of healthcare and clinical trials.

Other skills

Familiarity with big data analytics and data mining techniques, enabling the candidate to analyse diverse datasets effectively.

Experience in interdisciplinary research, particularly in collaborative projects involving multiple scientific disciplines.

Proficiency in statistical analysis software such as R or Python, facilitating data interpretation and modelling.

Description of the research group(s) in which the doctoral candidate will be integrated

Katia Mattarozzi, Associate Professor of Psychology at the University of Bologna, leads research focused on top-down modulation of pain and Patient-Reported Outcome Measures (PROMs). She also spearheads the PANACEA ERASMUS+ Programme, which explores "Special Needs by Placebo" to Advise, Normalize, and Control its European Administration.

Bianca Maria Piraccini, Full Professor in Dermatology at the University of Bologna, specializes in disorders of skin appendages, hair, and nails, providing invaluable clinical insights into dermatologic conditions. Gastone Castellani, Full Professor of Applied Physics at the University of Bologna, brings expertise in big data and algorithmic decision-making, leading EU projects such as HARMONY, Genomed4All, and SYNTHEMA, all dedicated to Big Data Analytics and Machine Learning.

Emanuela Marcelli, Associate Professor of Biomedical Engineering at the University of Bologna, offers expertise in utilizing innovative technologies and sensors to monitor health conditions and assess therapeutic treatment effects in patients.

Arianna Bagnis, Postdoctoral Researcher at the University of Bologna, focuses on top-down modulation of pain and serves as project manager of the PANACEA program, further enhancing the group's understanding of placebo mechanisms.

Furthermore, the collaboration with Andrea Evers, Full Professor of Health Psychology at the University of Leiden, strengthens the group's expertise in placebo studies, particularly in dermatology, through their long-term partnership in the PANACEA ERASMUS+ project. The group's affiliation with the European Academy of Dermatology & Venereology (EADV) provides access to a broader network of dermatologists and researchers, fostering knowledge exchange and collaboration.

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

Candidate will have access to robust computing resources necessary for processing and analysing large-scale datasets such as in-house cluster of 20 servers, equipped with 64-core Xeon processors, >20TB Hard Disk and 256 GB RAM each, for bioinformatics analyses purposes, equipped with all available software suites (Python, R, Julia, Matlab, C++). Leveraging big data methodologies, including data mining and machine learning algorithms, our computational infrastructure will enable the integration and analysis of diverse datasets such as Randomized Controlled Trials (RCTs) data, electronic health records, and patient-reported outcomes. This computational framework will serve as the cornerstone for identifying patterns and predictors associated with placebo and nocebo responses, ultimately leading to the development of predictive models for treatment outcomes.

Collaboration networks involving the research team

- European Academy of Dermatology & Venereology (EADV)
- A non-academic institution providing access to a broader network of dermatologists and researchers. EADV serves as a platform for knowledge ex-change and collaboration, further enriching the program's scientific ecosystem.
- Panacea Cooperation Partnership https://site.unibo.it/educationonplacebo/en
- SIPS https://placebosociety.org/home
- EFIC https://europeanpainfederation.eu/
- University of Cambridge UK
- Politecnica University of Madrid ESP

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Project HARMONY; Funding: Innovative Medicines Initiative (IMI) and European Union's Horizon 2020 Research and Innovation Programme and the European Federation of Pharmaceutical Industries and Associations (EFPIA); Unit Project Leader: Gastone Castellani, University of Bologna;

Doctoral Position

Evolutionary perspective on health and medicine through the lens of paleogenomics

Doctoral Programme

Life Sciences and Biotechnology

Description of the doctoral position's main topic

Disentangling the history of human biological adaptation has fascinated scientists for more than a century. How did humans evolve in response to the new environments they encountered while expanding from Africa? How ancient human populations responded genetically to cultural changes such as the dietary shifts associated with the onset of agriculture? Do our past adaptations have consequences for health and medicine today?

Since 2010, advancements and the subsequent broad applications of next-generation sequencing techniques have enabled rapid and cost-effective sequencing of eukaryotic genomes and paved the way for a genomic era in the field of ancient DNA, which is now established as a new discipline, called Paleogenomics. Ancient DNA provides a glimpse into the genetic history of humans across the globe over the past millennia. The study of paleogenomic data made it possible to examine the deep past of human populations, and to explore the genetic makeup and adaptation dynamics of archaic lineages and of ancient and present-day populations. The sequencing of Neanderthal and Denisovan genomes has revealed a complex history of admixture between archaic humans and the ancestors of modern humans. Consequently, archaic sequences became part of the modern human gene pool, possibly influencing life and health of our ancestors, as well as of living individuals. For example, lines of evidence suggest that genetic variants introgressed from archaic hominins may have affected genes associated with immunity, or pharmacogenes - genes involved in drug metabolism - as these genes can relate to changing environments, and beneficial variants may have been positively selected by modern humans. In addition, modern human population dynamics had a pivotal role in shaping the current pattern of genomic diversity. Within the past 10,000 years, we observed two main genetic turnovers in Europe, namely the Neolithic transition and the expansion of farming communities from

Anatolia, and the migration from Pontic-Caspian Steppe during Bronze Age. These population dispersals, changing lifestyle and higher population density, may have resulted in increased transmission of pathogens, driving selection of variants in immune response genes, and triggered important changes in the adaptive evolution of our species both at local and global scales. While the availability of thousands of ancient genomes gives us the opportunity to unveil the history of human adaptation at unprecedented depth and precision, the study of the contribution of archaic and ancient alleles to current human health is still in its infancy. Shedding light on adaptive evolutionary dynamics of our species would promote a more comprehensive reconstruction of our past, sharpening the current understanding of our present. The results of this project will pioneer the field of Evolutionary Medicine, thus providing significant contributions to biomedical research and medical applications.

Sub-themes of the doctoral position's main topic (if any)

The availability of thousands of high-quality ancient genomes can help the identification of rare variants introgressed from archaic and ancient humans into the modern populations to address key questions related to human health and disease. Studies on modern humans shown that differential outcomes after infection are due to specific DNA mutations that alter host defense mechanisms. However, little is known about adaptation of archaic and ancient humans to past environments and pathogens. Therefore, studying genetic variants associated with infectious-disease risks in fossil remains, highlight the potential value of paleogenomics in medicine.

Recent studies pointed out the value of using ancient DNA to reconstruct the evolutionary history of immune disorders and past epidemics. Kerner et al. (2021) found a tuberculosis risk variant in ancient genomes that has evolved under strong negative selection over the past two millennia, probably reflective of the pressure imposed by Mycobacterium tuberculosis. Ancient DNA can also be used to identify advantageous mutations that are positively selected over time through pathogen exposure. For example, some immunity-related genes under positive selection have been found to be associated with the Neolithic transition in Europe. This is the case for IL1R2, for which high levels of expression are associated with protection against several autoimmune disorders.

Lastly, the study of genetic variants inherited from the admixture between modern and archaic humans can help us to disentangle adaptation processes to new environments and host resistance to pathogens. An example is the adaptation of Tibetan populations to high altitudes due to the introgression of adaptive alleles

from Denisovans. Another case is provided by a Neanderthal haplotype at the antiviral OAS1 that was recently shown to be associated with protection against severe COVID-19. These findings can open new avenues to find candidate drug targets in disease treatment.

Keywords:

- Legacy of archaic humans
- Immune disorders
- Adaptation to pathogens
- Co-evolution pathogens-host

Potential Supervisors

Silvia Ghirotto, Andrea Benazzo, Silvia Fuselli

Doctoral candidate's desirable skills and competences

Scientific and technical skills

The ideal candidate should have a graduate degree in biology, genetics, or a closely related field, and a strong interest in bioinformatics. The candidate should have a good computational background (basic knowledge of R, Python or Bash programming languages are mandatory); experience with cluster computing environments would be appreciated but it is not mandatory. He/she should also have a good population genetics background.

The work will focus intensively on bioinformatics and biostatistics to handle and analyze genomic data. The candidate will have a primary role in the processing and management of genomic data (ancient and modern), as well as the development of methods to infer demographic and evolutionary processes using genomic data.

Other skills

We are looking for a motivated PhD candidate, hardworking, and interested in addressing scientific problems with rigor and creativity. The candidate will need to communicate and write in English; fluent level of English is recommended.

Description of the research group(s) in which the doctoral candidate will be integrated

The candidate will be supervised by Prof. Silvia Ghirotto (associate professor at UNIFE since 2018, total citations 1521, h-index 23, (Scopus, 19/03/2024), qualified to full professor in Genetics and in Anthropology

in 2021), a geneticist specialized in population genetics. She published 53 original papers, almost all about population genetics analysis of human evolutionary history and development of methods for the analysis of genomic data. The complete list of Prof. Ghirotto's publications can be found here: https://scholar.google.com/citations?hl=it&user=ZiSeXpIAAAAJ. At the moment, Prof. Ghirotto is leading a national project involving five different academic units, aiming to reconstruct the demographic and evolutionary history of human presence in the three main Mediterranean islands (Sicily, Sardinia and Corsica); she is also responsible for the UNIFE unit in other two national projects, aiming to shed light on the past human dynamics in the Italian peninsula and to perform evolutionary inference of past processes from dental calculus metagenomic data. She is also directing a national project aiming to study the origin of social inequalities in Northern Italy from a paleogenomic perspective. Prof. Ghirotto coordinates a research group (Ghirotto Lab, website: https://ghirotto-lab-at-university-of-ferrara.github.io/) composed by two postdoctoral researchers, two PhD students, and a fellowship researcher. The research group has extensive experience in bioinformatic analysis and in statistical methods applied to the analysis of modern and ancient genomic data. The research work focuses on the reconstruction of evolutionary processes that shaped current and past patterns of genomic variation, exploring and interpreting human genetic variation together with evidence from other fields, such as anthropology, archaeology, and linguistics. Prof. Ghirotto group is also primarily involved in the development and the analysis of statistical methods, mainly based on computer simulations and machine learning approaches, to infer past population dynamics and to test among different evolutionary scenarios. Prof. Ghirotto research group is integrated within the Population Genomics laboratory of the University of Ferrara. The Population Genomics laboratory team is composed by Prof Guido Barbujani, whose research focuses on human evolutionary genetics, Prof Giorgio Bertorelle and Dr Andrea Benazzo, whose research focuses on evolutionary and conservation genomics, Dr Silvia Fuselli, whose research focuses on molecular evolution and pharmacogenomics, Prof Chiara Scapoli and Dr Elisabetta Mamolini, whose research focuses on human genetics.

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The host will give all the support in the completion of the project goals. Life Sciences and Biotechnology Department at UNIFE has a long-lasting tradition of advanced studies in populations genetics and genomics, micro and macro evolutionary processes and biostatistics. It has a large team of people working in transversal and multidisciplinary themes. It frequently hosts visiting researchers. The doctoral candidate will be

integrated into Prof. Silvia Ghirotto group, in the Population Genomics laboratory, which has an impressive reputation internationally for the quality and productivity of its members and for the breadth of its expertise. It is a highly attractive laboratory with researchers that cover a broad area of expertise's for the study of populations evolutionary history and development of methods for the analysis of genomic data. Upon beginning of the project, UNIFE will provide a desk space, access to a workstation, web, digital library, high-throughput computational resources, personalized assistance on administrative matters, etc. The host offers magnificent facilities and infrastructure to carry out this project at a European scale. It offers a High-Performance Computing (HPC) System composed by 14 computing nodes, 5 storage servers and 2 login nodes. The total amount of computing resources is 824 cores, 2.9 TB of RAM and 205 TB of storage capacity; access through proposal submission to large CINECA (Consortium of 70 Italian Universities) computing resources. The candidate will have the opportunity to participate in the weekly group seminars, guest talks and discussions sessions to capitalize on local networking chances, increase collaborations with geneticists and bio-staticians. He/she will be working in an inter-disciplinary environment and in a highly dynamic and enriching research institution. UNIFE have an International Research office providing all the assistance needed to staff and research fellows.

Collaboration networks involving the research team

The PI of the research group, Prof. Silvia Ghirotto, has been primarily involved in national and international collaborations which aimed to reconstruct past population dynamics through a multidisciplinary approach, and has documented experience in leading research projects, as PI or local coordinator (PRIN 2017, FIR 2018, PRIN 2020, PRIN-PNRR 2022, PRIN 2022). The research group has several well-established national and international collaborations in different fields (anthropology, archaeology, molecular anthropology, bioinformatics and population genetics) from which the candidate will benefit to ensure the achievement of the project goals. The PI has an established collaboration (since 2015) with the multidisciplinary DFG Center for Advanced Studies "Words Bones Genes Tools" of the University of Tubingen, of which she is an External Scientific Member. Collaborations with national molecular anthropologists from the University of Florence (Prof. David Caramelli, Dr. Stefania Vai and Prof. Martina Lari); international archaeologists from the CNRS in the University of Bordeaux (Prof. Solange Rigaud); populations geneticists from the University of Cambridge (Prof. Andrea Manica) and Muséum National d'Histoire Naturelle in Paris (Prof. Stefano Mona).

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- PRIN2017 - 1000 Ancient Italian Genomes: Evidence from ancient biomolecules for unravelling past human population Dynamics (AGED) Ministero dell'Istruzione dell'Università e della Ricerca (MIUR) – Bando PRIN. PI: Prof. David Caramelli. Co-PI: Prof Silvia Ghirotto, Prof. Donata Luiselli, Prof. Olga Rickards, Prof. Sarti Lucia, Prof. Sineo Luca. Team members are responsible for collecting, processing, and analyzing whole genome data from both modern and ancient humans.

- PRIN2020 - Crossing the sea: ancient and modern human genomes to study the evolutionary dynamics of Sicily, Sardinia and Corsica. Ministero dell'Istruzione dell'Università e della Ricerca (MIUR) – Bando PRIN. PI: Prof. Silvia Ghirotto. Co-PI: Dr. Stefania Vai, Prof. Paolo Francalacci, Prof. Luca Sineo and Prof. Marco Sazzini. Team members are responsible for collecting, processing, and analyzing whole genome data from both modern and ancient humans.

- PRIN2022 – Investigating the transition from hunter-gathering to farming in Southern Italy through metagenomic and population genetic analysis of ancient human dental calculus. Ministero dell'Istruzione dell'Università e della Ricerca (MIUR) – Bando PRIN. PI: Prof. Martina Lari. Co-PI: Prof. Silvia Ghirotto. Team members are responsible for collecting, processing, and analyzing whole genome data from dental calculus ancient samples.

- PRIN-PNRR2022 – The origin of social inequalities in Northern Italy: clues from ancient genomes. Ministero dell'Istruzione dell'Università e della Ricerca (MIUR) – Bando PRIN-PNRR. PI: Prof. Silvia Ghirotto. Co-PI: Dr. Stefania Vai. Team members are responsible for collecting, processing, and analysing whole genome data from archaeological human remains.

- BANDO A CASCATA - Progetto "NATIONAL BIODIVERSITY FUTURE CENTER - NBFC" SPOKE 3 "ASSESSING AND MONITORING TERRESTRIAL AND FRESHWATER BIODIVERSITY AND ITS EVOLUTION: FROM TAXONOMY TO GENOMICS AND CITIZEN SCIENCE". Project title (in Italian): Biodiversità ittica nel basso corso del fiume Po: un modello di studio degli effetti dei cambiamenti globali nei grandi fiumi (BioPo).

Doctoral Position

Big-data from single-cell multiomics in somatic stem cells for clinical application

Doctoral Programme

Molecular and Regenerative Medicine

Description of the doctoral position's main topic

Since 1980s, cultures of human epithelial cells (keratinocytes) have been extensively used in clinical applications to regenerate a functional cornea and epidermis in patients affected by severe burns. first successful combined cell and gene therapy for patients suffering from a specific form of Epidermolysis Bullosa (EB), namely recessive LAMB3-dependent Junctional EB (JEB), was pioneered by this research group (Mavilio et al., 2006). This approach relied on the use of transgenic epidermal grafts, prepared from clonogenic keratinocytes cultures transduced with a γ-retroviral vector carrying full-length LAMB3 cDNA (Mavilio et al. 2006, De Rosa et al. 2014, Bauer et al, 2017; Hirsch et al., 2017). It has been demonstrated that combined ex vivo cell and gene therapy can be lifesaving (Hirsch et al., 2017). We were able to restore virtually the entire epidermis of a 7-year-old child with a devastating form of JEB, having very poor prognosis, using a live-saving transgenic epidermal cultures (Hirsch et al., 2017). 8 years after grafting the child's transgenic epidermis is stable and robust (Kuckelhaus et al., 2023). Clonal tracing, using proviral integrations as clonal genetic marks, performed on the regenerated transgenic epidermis, has formally proven that the human epidermis is sustained solely by self-renewing long-lived stem cells. These stem cells, identified as holoclone-forming cells, give rise to pools of short-lived transient amplifying (TA) progenitors, which in turn produce meroclones and paraclones.

JEB represents a small percentage (~5%) of all EBs (Fine, 2016), and several hindrances hamper ex vivo gene therapy for other forms of EB: i) over 50% of EB forms are dominantly inherited, hence cannot be tackled by viral-mediated gene addition. ii) current gene editing approaches would transduce epidermal stem cells with insufficient efficiency. iii) holoclone-forming cells cannot be prospectively isolated, since specific cell membrane markers allowing their isolation have not yet been identified.

Microarray and single cell RNA-seq data have been used to understand the basic mechanisms of stem cell function in culture (Enzo et al. 2021). We confirm that holoclone-forming cells display stem cell features, such as genes regulating DNA repair, chromosome segregation, spindle and microtubule organization and telomerase activity.

In this project, we aim to combine cutting-edge single-cell transcriptomic and epigenetic data with Artificial Intelligence to better characterize squamous epithelial stem cells at a molecular level. All this data will be used for the creation of an integrated atlas of in vitro cultured human epithelial cells from the different anatomical compartment. The multiomic data will be subjected to machine learning algorithms to develop a user-friendly tools for estimating the characterization of each type of cells, providing a comprehensive understanding of the molecular profile of stem cells, transient amplifying progenitors, and fully differentiated cells from each of these epithelia.

Our international network in regenerative medicine and gene therapy provides a fertile ground for PhD students. Many of these bright minds, having honed their skills and knowledge during their PhD with us, subsequently joined other esteemed groups led by renowned experts in the field. This exchange contributes to the advancement of the scientific community and perpetuates a legacy of excellence and innovation.

Sub-themes of the doctoral position's main topic (if any)

None

Potential Supervisors

Michele De Luca, Graziella Pellegrini, Laura De Rosa.

Doctoral candidate's desirable skills and competences

Scientific and technical skills

The candidate should have a Master's degree in science, preferably in molecular biosciences (molecular, cellular, and developmental biology, genetics, or genomics). Practical experience in developmental biology, genetics, microscopy, genomics, or bioinformatics is an advantage.

Other skills

The candidate should be able to communicate well in both written and spoken English.

Description of the research group(s) in which the doctoral candidate will be integrated

The research group is led by three principal investigators: Prof. Michele De Luca, Prof. Graziella Pellegrini, and Prof. Laura De Rosa. Additionally, there are three senior researchers (Dr. Elena Enzo, Eustachio Attico, and Eleonora Maurizi) who oversee the coordination of postdoctoral fellows and PhD students. Our research focuses on understanding the molecular mechanisms of self-renewal and differentiation of epithelial cells, as well as the application of cell and gene therapy for various diseases affecting the cornea, skin, and respiratory tract. We conduct primary keratinocyte cultures and perform single-cell transcriptomic and epigenomic experiments, including ATAC-seq and gene expression analysis. Additionally, we employ proteomic and transcriptomic analyses such as Western blotting, immunofluorescence, real-time PCR, and digital PCR. Furthermore, we develop methods to transduce human primary keratinocytes using lentiviral or retroviral vectors, as well as CRISPR-based gene editing techniques. We developed clinical trials for the use of these cells in clinics. Additional information and full list of publication could be found here: https://www.cmr.unimore.it/en/homepage-2/

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral candidate will conduct her/his activities at the Centre For Regenerative Medicine "Stefano Ferrari" in the University of Modena and Reggio Emilia is a 3-floor building of 4.000 sq metres fully equipped for biochemistry, molecular biology, histology, cytology. Core facilities include confocal and time-lapse microscopy, laser microdissection, X-ray cell irradiation, bioinformatics support, flow-cytometry, 5 fully equipped BL2 cell culture rooms, single-cell transcriptomic platforms (Chromium X from 10X Genomics, Droplet digital PCR from Bio-rad, Tapestry from Mission Bio) and library preparation.

Collaboration networks involving the research team

Our research team prides itself on its extensive collaboration networks, spanning across various academic disciplines and industry sectors. These networks serve as invaluable resources for doctoral candidates, offering unique opportunities for interdisciplinary exchange, access to cutting-edge technologies, and exposure to diverse perspectives.

Within academia, our team has established collaborations with national and international leading institutions and experts in fields closely related to the Futuredata4EU project. We collaborate with:

- Prof. Bicciato and Prof. Forcato at the University of Padua for the bioinformatic analysis.
- Prof. Paiardini and Prof. Rinaldo for protein structure prediction.
- Dott. Tommaso Selmi from Centro Nazionale delle Ricerche in Milano for epitranscriptomics analysis.
- The European partners in the Regenerate-IT consortium to share methods and tools related to the regenerative medicine field.
- Prof. Mariaceleste Aragona in ReNEW at Copenhagen to study the crosstalk between fibroblast and epithelial cells.

Through these connections, doctoral candidates gain access to specialized knowledge, methodological expertise, and collaborative research opportunities, enriching their academic experience and broadening their professional networks.

Furthermore, our team maintains strong ties with industry partners, including biotech companies (es Holostem s.r.l.), government agencies (es, EMA, Aifa), and non-profit patient organizations (es. Le ali di Camilla). These collaborations offer doctoral candidates real-world insights into the practical applications of their research, as well as opportunities for technology transfer, industry placements, and entrepreneurship initiatives.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- Regenerate-IT Learning From Animals How To Regenerate: multidisciplinary training programme in regenerative biology - Marie Skłodowska-Curie Actions – Doctoral Networks (MSCA-DN), PI Michele De Luca
- Custom-designed gene editing of induced epidermal stem cells for gene therapy of genetic diseases of squamous epithelia (HOLO-GT)- - Holo-GT- ERC project, ERC-ADG- Advanced Grant - PI Michele De Luca
- Cellule staminali e medicina personalizzata: il caso della Epidermolisi Bollosa (HG7 3.0) - POR-FESR 2021-2027 PI Michele De Luca
- A plot in vitro and in vivo study for molecular characterization of epidermal stem cells and quality and safety assessment of epidermal cultures for combined cell and gene therapy – PRIN 2022 – PI Michele De Luca

- Gene-editing allele specifico mediato da CRISPR-Cpf1 ingegnerizzate per il trattamento delle patologie oculari nella sindrome da Ectrodattilia-displasia ectodermica-labiopalatoschisi (EEC) - Telethon: PI Michele De Luca

- A new strategic model for a sustainable development and maintenance of advanced therapies on the market- FISA-2022-00928 – PI Graziella Pellegrini

- The Empty Nose syndrome, investigations propaedeutic to in vivo studies – PRIN 2022 – PI Graziella Pellegrini

- High-resolution study of translational dynamics in human epithelial stem cells – PRIN 2022 – PI: Dott. Tommaso Selmi, CO-PI: Elena Enzo

- Unravel fibroblast-epithelial crosstalk supporting keratinocytes self-renewal to improve skin graft production. Leo Foundation –PI Prof. Mariaceleste Aragona, Third part: Elena Enzo.

UNIVERSITÀ DI PARMA (UNIPR)

A Radio-immune-genomic Approach and Big Data Integration to Identify Predictive Signatures for the Response to Immunotherapy in Solid Tumors

Doctoral Position

A Radio-immune-genomic Approach and Big Data Integration to Identify Predictive Signatures for the Response to Immunotherapy in Solid Tumors

Doctoral Programme

Translational Medical and Surgical Sciences

Description of the doctoral position's main topic

Immune Checkpoint Inhibitors (ICIs) have prompted a paradigm shift in the treatment landscape of multiple cancer types achieving unprecedented results, although still in a limited subset of patients (ranging from 20 to 30%). Thus, the identification of patient- and tumor-specific biomarkers able to guide patient selection and clinical decision making is of paramount relevance. Current artificial intelligence (AI) models largely operate in the domain of a single modality, partly neglecting the overall clinical context, which inevitably reduces their potential. Integration of different data modalities may increase robustness and accuracy of prognostic and predictive models, bringing AI closer to clinical practice. AI approaches allow exploitation of high-dimension oncological data in research, being also capable of discovering novel patterns within and across modalities suitable for explaining differences in patient outcomes or treatment resistance. A large amount of biomarkers (genomic, epigenomic, transcriptomic, pathomic, immunomic, radiomic) related to IO's efficacy can be extracted with AI techniques across a wide variety of different cancer types, demonstrating the general applicability of the models.

The common theme of this project is based on the premise that tumor heterogeneity, and response to ICIs, can be untangled by a multidisciplinary strategy involving the integrated analysis of radiologic, immunophenotypic and genomic/transcriptomic clues.

In detail, the following research fields will be explored, with the ultimate aim to develop a multiomic profile endowed with the potential to provide a non-invasive approach to advanced cancer patients and predict the response to immunotherapy:

- Immunophenotypic analysis: definition of Tumor Immune Microenvironment (TIME) on tissue specimens; flow-cytometric analysis of peripheral blood immune cell subpopulations and ELISA immunoassay for soluble mediators at baseline and during treatment.
- Genomic and transcriptomic analysis: Next Generation Sequencing (NGS) and Nanostring technologies will be employed for molecular characterization using a DNA/RNA based assay.
- Radiomic analysis: Extraction of high throughput radiomic features from CT scans at baseline and during treatment.
- Bioinformatics analysis: AI methodologies (i.e. standard machine learning [ML] and deep learning [DL]), broadly divided into supervised (random forest, support vector machine), semisupervised (multiple-instance learning, graph convolutional network) and unsupervised (principal component analysis, k-means clustering) learning will be applied to our omics data.

In summary, our project aims to apply AI based analytic techniques in a standardized and nationally shared treatment setting for advanced cancers. The required cooperation between different professionals for obtaining an adequate development of the essential multimodal strategy leads to an overall improvement of assistance levels which translates in an enhanced delivered quality for the patients, perfectly integrating with the national healthcare system policy and with the purpose of the present Call.

Sub-themes of the doctoral position's main topic (if any)

None

Potential Supervisors

Marcello Tiseo, Nicola Sverzellati, Giovanni Roti

Doctoral candidate's desirable skills and competences

Scientific and technical skills

Specialization in Oncology or in Genetics is a plus, but not essential. Previous research experience is a plus.

Soft skills

The candidate should be able to work independently, take initiative, adopt critical judgment and demonstrate ability to work in team. In particular, he/she should be open to the multidisciplinary approach needed to

realize this project. The project will include several network wide educational events and a secondment, for which travel, communication and social skills are required.

Other skills

Proficiency in written and spoken English is crucial. Knowledge of data analysis and statistics is essential.

Description of the research group(s) in which the doctoral candidate will be integrated

Our project has been conceived drawing from a strong biological rationale, using innovative techniques to bridge the unmet need of predictive biomarkers of IO treatment efficacy in patients with advanced cancer. The availability of modern instruments and the recognized experience of the participating subjects in the field, clearly supply quality to the project and allow an easy transferability and applicability of the obtained results to daily clinical practice. Multidisciplinary collaborative approach is a central issue for building personalized oncology and for devising novel treatments. Accordingly, the idea originating the COFUND research project 'Futuredata4EU' comes from the urgent need of exploring, innovating, integrating, and validating existing and novel approaches in a new objective unified framework for enabling in the current clinical practice, patient-specific methods and tools for the intervention and the follow-up of personalized therapeutic strategies. The involvement of several operative units and departments from different institutions in this project strengthens an already well-established cooperative attitude. Our project provides the opportunity to share innovative multiomic analysis of blood and tissue samples, high throughput extracted imaging features thus favouring the diffusion of the related knowledge. Medical Oncology core: responsible for interaction between clinicians and laboratory team; involvement in patient accrual and screening, obtaining informed consent, patient management and assessing treatment outcomes. Radiology and Bioinformatics core: the Radiology team will focus on CT evaluations and extraction of radiomic features. The bioinformatic team will support AI-based analyses of multiomic data. Histopathology core: responsible for diagnostic and immunohistochemical (IHC) analysis, assessment of patient immune profiles. Immunobiology core: responsible for characterization of circulating immune profiling based on Fluorescence Activated Cell Sorting (FACS) and ELISA analyses. Genetic-molecular core: responsible for development of genetic-molecular design of the project, interaction between laboratory team and clinicians and the management of biological samples.

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The project will take place at the Medical Oncology Unit of the University Hospital of Parma which is a high volume clinical centre, provided by Phase I and clinical research trial units with dedicated nurses, project managers and available laboratories. The research/diagnostic laboratory (CoreLAB) at the University Hospital of Parma contains the following technologies/expertise: nucleic acids extractor (MagCore HF16 Plus, RBC Bioscience Corp.), NGS Library Prep workstation (Hamilton MicroLab STARlet), quality control of nucleic acid and libraries (Agilent 4200 TapeStation System), Real Time PCR (Life Technologies, Roche), digital droplet PCR (Bio-Rad), NGS instruments (Illumina MiSeq and NextSeq550Dx) and Ella Automated Immunoassay System (Bio-Techne). At the Pathology Unit a MagCore HF16 Plus (RBC Bioscience Corp.), two NGS instruments (MiSeq, Illumina and IonS5, Life Technologies) and Nanostring technology are available. The platform available for FACS analysis is a Becton Dickinson FACSCelesta flow cytometer with BV configuration, specifically dedicated to translational studies. The system operates with BD FACSDiva™ software, a collection of easy-to-use tools for flow cytometer and application setup, data acquisition and data analysis. The Research and Innovation Unit provides methodological and biostatistical expertise, study quality assurance and control and management of financial aspects. The Ethics Committee Secretariat offers timely support to researchers, speeding up the submission process and ensure regulatory compliance. In the highly qualified Unit, specifically trained personnel operate in compliance with Good Clinical Practice, by mean of Standard Operating Procedures. A team of biologists and bioinformaticians fully involved in research projects are available to embrace the PhD candidate and to support him/her.

Collaboration networks involving the research team

To achieve the objectives of this project, a variety of techniques will be required. It is impossible for a single project leader to have in his/her laboratory the expertise necessary to perform complex interdisciplinary experiments. The increase in scientific interaction among the five cores of this project in the last four years has strengthened the goals of our current proposal, which are the foundation of the research planned here. Our ongoing funded projects have been mainly focused on the understanding of the mechanisms underlying inter- and intra-tumor heterogeneity and its impact on the clinical response to IO. The critical role played by genetic and immune pathways in cancer evolution and response to treatment and their non-invasive decoding by radiomics have helped us to formulate the new hypotheses of this COFUND research project.

Most importantly, the funded research has prompted the group to raise new questions concerning the biology of the cancer-immunity cycle and its translation into clinical ground. During our frequent meetings in academic and clinical contexts, it became apparent to all of us that our common interest in optimizing the treatment of solid tumors, which increasingly affect the overall population, would have served our purposes better if our different but complementary expertise and objectives would have been combined in an integrated multidisciplinary research project. On the basis of recent results obtained in our laboratories, the five core leaders and associates were in agreement and felt rather strongly about the possibility to uncover the underpinnings of the heterogeneous response to IO by multiomic strategies. This novel approach was perceived as a crucial point of departure in the present investigation. It is conceivable that the future doctoral candidate would benefit not only from the high level of individual expertise on each field of the project but also from the strong motivation of the entire research group driven by the potential achievement of practice changing results. Moreover, acquiring the knowledge on AI based big data analysis represents an actual almost inevitable skill favouring the future integration of the candidate in academic or clinical environments.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- PRIN Granted Project (P.I. Prof. Sebastiano Buti – 2 years) – "LINking CHOLesterol hoMeostasis with immune-inflammatory profiles to predict immunotherapy efficacy in patients with metastatic renal cell carcinoma and non-small cell lung cancer: the LINCHOLM study"
- BANDO RICERCA FINALIZZATA 2021 (P.I. Prof. Marcello Tiseo, RF-2021-12374037 – 3 years
- "A Multiomic Approach to Identify Prognostic and Predictive Signatures in Advanced Non-Oncogene Addicted Non-Small Cell Lung Cancer (NSCLC) receiving Immunotherapy"
- University Granted Project (FIL-QI 2021, P.I. Prof. Marcello Tiseo – 2 years) – "Identification of Prognostic and Predictive Radio-Immune-Genomic Signatures in Small Cell Lung Cancer (SCLC) and Malignant Pleural Mesothelioma (MPM)"
- Region University Research Granted Project - FIN-RER 2020 - (P.I. Prof. Marcello Tiseo – 3 years) - "A multiomics approach to identify prognostic and predictive features of immunotherapy in solid tumors"

- AIRC Granted Project (P.I. Prof. Nicola Sverzellati, IG 2019, ID. 23606 - 5 years) - "A Radio-Immuno-Genomic Approach to Identify Prognostic and Predictive Models for the Response to Immunotherapy in NSCLC".

UNIVERSITÀ DI BOLOGNA (UNIBO)

Data Analytics and AI for supporting legislative assistance at WIPO: a neuro-symbolic approach

Doctoral Position

Data Analytics and AI for supporting legislative assistance at WIPO: a neuro-symbolic approach

Doctoral Programme

Law, Science and Technology

Description of the doctoral position's general/main topic

- The project should analyse the data science and AI techniques for supporting the legislative assistance process in WIPO using normative documents, including Member States legislation, in order to extract legal knowledge, classify the main rules in selected areas of the patent law domain, monitoring the evolution of the domestic laws in this sector, identify common patterns and generate benchmark provisions to provide support to the legislative advice work carried out at WIPO. Prediction of future needs is another important goal for anticipating the assistance requested by Member States and enhancing the efficiency of delivering such services. The analysis of the big data (including data and documents and relationships between them) has the aim to detect, measure and address WIPO policies in the light of the Member States legislation to have more success in the regulative enforceability of the WIPO requirements.

The project includes three main steps:

1. analysis of the literature and the state of the art, using the data and documents collected from WIPO and Member States. Clean and harmonizing the data/document is fundamental for avoiding bias, distortion, and undesirable discrimination effects. Akoma Ntoso OASIS standard XML is used for harmonization and data cleaning.

2. Model development for elaborating the data using data science and AI models and techniques. In this step, several techniques will be compared using hybrid and neuro-symbolic approaches (symbolic, sub-symbolic, and knowledge graph representation).

3. Developing of dashboard for visualizing the results using metrics, indexes, and benchmarking techniques to explain the results.

The project includes a period at least of 12 months in WIPO premises for making experiments in place, tuning the model, to evaluating the results with the end-users.

Sub-themes of the doctoral position's main topic (if any)

None

Potential Supervisors

Monica Palmirani, Rodríguez Doncel Víctor, Bart Verheij.

Doctoral candidate's desirable skills and competences

Scientific and technical skills

- Good knowledge of Artificial Intelligence (AI) and Explainable AI (XAI)

- Familiarity with logic and formal reasoning methods

- Excellent analytical and problem-solving skills

Other skills

- Knowledge of legal reasoning and argumentation frameworks

- Experience with deontic logic and normative concepts

- Programming skills (e.g., Python)

Description of the research group(s) in which the doctoral candidate will be integrated

The group is composed by several other PhD candidates, researchers and network of full professors.

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The University Library System offers collections of books, magazines, exam texts, databases on traditional and electronic media; and manages advanced bibliographic services, specialized for disciplinary fields, to support teaching and research. The System is divided into 27 libraries and over 75 access points with 6,000

reading places. The overall heritage consists of approximately 4,000,000 volumes of press, 43,000 paper periodicals, 43,000 online periodicals, 152,000 ebooks, dictionaries and encyclopaedias, 500 databases, over 8000 theses doctoral and degree courses, 80,000 teaching materials in digital format. Among the services available: online catalogues, consultation, loan local and inter-library, supply of documents, assistance and guidance in bibliographic research through tutorials and services online, digital library platforms for archiving and preserving digital documentation produced at the University. We have a room for the lectures and a room for the PhD candidates where they can share their knowledge with interdisciplinary discussions. Finally, we have the possibility to have the support of the cloud computing equipment from UNIBO data factory and CINECA.

Collaboration networks involving the research team

"Law, Science and Technology" is an interdisciplinary international PhD programme that involves a network of about 20 universities in Europe and extra-EU (e.g., Stanford, University of Pittsburgh, La Trobe – Australia, etc.). It hosts MSCA-EJD PhD students.

We have a strong connection with the AI community thanks to the PNRR project "Future Artificial Intelligence Research (FAIR)".

We have a strong connection with CINECA thanks to the PNRR project on HPC (ICSC National Research Centre in High-Performance Computing, Big Data and Quantum Computing).

The topic of IPR is fundamental for supporting the digital transformation of society, emerging technologies (e.g., AI), the global research. Good IPR management supports the EU economy to compete with a robust framework where the shareability of knowledge and protection of intellectual rights are balanced for fair growth. WIPO will be involved intensively in the project.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- ERC CompuLaw, Giovanni Sartor, Computational Judiciary System

- ERC HypermodeLex, Monica Palmirani, eLigilsation and AI

- JUST, FACILEX, Giuseppe Contissa, eJustice
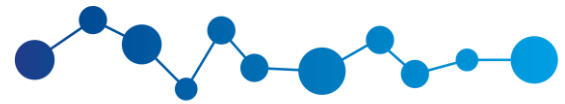
- CERV, FAST-LISA, Francesca Curi, Hate Speech and Human Rights

- PON, Digital Twins, Antonino Rotolo, Smart Cities

UNIVERSITÀ DI FERRARA (UNIFE)
Unravelling the Evolution of Lithic Tools Morphology: Leveraging Big Data and Geometric Morphometrics in Archaeological Analysis

Doctoral Position

Unravelling the Evolution of Lithic Tools Morphology: Leveraging Big Data and Geometric Morphometrics in Archaeological Analysis

Doctoral Programme

Human Sciences

Description of the doctoral position's general/main topic

The advent of big data has revolutionized various fields, including archaeology, by enabling the analysis of vast datasets to uncover hidden patterns and insights. In the realm of lithic analysis, geometric morphometrics offers a powerful approach to understanding the evolution of stone tool technology. Geometric morphometrics provides a framework for quantifying and analysing shape variation, allowing to explore the intricate morphological features of lithic instruments in unprecedented detail. By leveraging big data methodologies (statistical methodologies such as clustering and regression on larger datasets, aided by advanced tools), researchers can process large quantities of morphometric data collected from diverse archaeological sites, spanning vast temporal and geographical scales. This project will focus on the synergy between big data analytics and geometric morphometrics in unravelling the complexities of lithic tools (belonging to a specific chronological period – from Lower Palaeolithic to Neolithic - or representing a ubiquitous cultural innovation), shedding light on ancient hominin behaviour, cognitive abilities, and technological innovations.

The project fits into an international context constituted by the network of research centers focusing on prehistory. 36 institutions across Europe, Asia, Africa, and the Americas are already connected through the International Erasmus Mundus Master in Quaternary and Prehistory, and the development of this theme would represent an advancement in research methodologies (that can then be applied in a broader context generally to all cultural artifacts) in the cultural interpretation, of prehistoric artifacts. At the national and regional levels, the project will strengthen collaborations between museums and universities through the

implications for the museumization of lithic industries, which are often regarded as a non-speaking heritage and challenging to disseminate.

After conclusion, it opens a plethora of career opportunities for researchers specialized in merging cutting-edge technology with archaeology. Professionals adept in big data analytics, statistical methodologies, and geometric morphometrics are in high demand across academic, research, and industry sectors. Positions such as data scientists specializing in archaeology, research analysts focusing on cultural heritage, and specialists in digital archaeology are just a few examples of the diverse career paths available. Additionally, there are opportunities for collaboration with museums, cultural heritage institutions, and government agencies involved in archaeological preservation and research. Furthermore, this project lays the groundwork for interdisciplinary collaborations, offering avenues for archaeologists to collaborate with experts in computer science, data engineering, and machine learning. Overall, the skills and insights gained provide a solid foundation for pursuing a rewarding career at the forefront of archaeological innovation and data-driven research.

Sub-themes of the doctoral position's main topic (if any)

None

Potential Supervisors

Marta Arzarello, Marco Peresani, Federica Fontana.

Doctoral candidate's desirable skills and competences

Scientific and technical skills

The candidate must necessarily possess the following skills:

- experience in using geometric morphometrics for contour analysis;
- knowledge of the technological approach to the study of lithic industries;
- understanding of human and cultural evolution throughout the Paleolithic;
- knowledge of basic statistics.

The following additional skills may be considered useful for carrying out the research project:

- Knowledge of the software R Studio;
- knowledge of the software Past;

- expertise in generative AI;

- ability to perform 3D scanning;

- knowledge of the fundamentals of Python programming;

- proficiency in at least two languages besides English;

- ability to structure a scientific article.

Description of the research group(s) in which the doctoral candidate will be integrated

The involved research group deals with interdisciplinary studies (with expertise in prehistoric archaeology, geology, palynology, human and vertebrate paleontology, radiometric dating, fossil DNA, cultural heritage management, museology and museography) on prehistory from its early phases up to the Neolithic. The doctoral candidate will be integrated into an international research network that has been conducting interdisciplinary and joint research in the field of prehistoric archeology for more than 20 years.

The research group is based on the collaboration between the University of Ferrara (Italy), the Muséum national d'Histoire naturelle de Paris (France), the Universitat Rovira i Virgilli (Spain), and the Instituto Politecnico de Tomar (Portugal). These partners include collaborations with associated partners from Asia, Africa and South America. The connection between these institutions was made definitively official in 2004 (the year in which the joint Erasmus Mundus Master in Quaternary and Prehistory financed by the EACEA was opened, still active) and to date has seen the joint development of numerous research and training projects (see point 17).

Concerning the study of lithic industries, specifically, the research group is seeking to develop an innovative methodology that goes beyond a techno-economic approach and allows highlighting cultural trends within a "phylogenetic" perspective. However, this approach requires the collection and processing of a large amount of data, which must necessarily come from extensive geographical areas. The research group conducts excavations in Europe, Africa, and Asia (excluding the Americas due to their relatively recent human habitation), which will facilitate the collection of the dataset regardless of the specific research project presented by the candidate. From a methodological point of view, the PhD candidate will be supported by a large group of researchers involved in the ERC project "Why late earliest occupation of Western Europe?". In this context, indeed, new approaches for interpreting lithic assemblages are being explored, approaches that include cladistics and geometric morphometrics. The latter requires the definition of a specific methodological protocol because there are no landmarks on lithic industries, thus contour analyses are

necessary, which can only be performed on 3D models. At the local level, at the University of Ferrara, the research group within the section of Prehistoric and Anthropological Sciences possesses all the necessary expertise, as its members span their expertise from the earliest European peopling to the latest Mesolithic hunter-gatherers. Additionally, the research group is conducting excavations at some of the key sites of utmost importance for defining the technical behaviors of Pleistocene Hominins: Pirro Nord, Grotta della Ciota Ciara, Riparo Tagliente, and Grotta di Fumane, to name a few of the most well-known ones.

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The environment in which the candidate will be welcomed will provide all the necessary equipment for conducting the research. At the Department of Humanities, the following equipment (already available) will be provided to the candidate:

- 3D workstation including a Breuckmann smartSCAN AICON 3D Systems that uses structured light technology. The smartSCAN 3D is versatile and perfect for use in various settings, making it particularly suitable for mobile or on-site applications. Its sensor setup enables scanning at triangulation angles of 30°, 20°, and 10°. This configuration enables precise measurement of even the most intricate object areas and geometries with exceptional detail.

- Equipped laboratory for creating 3D models through photogrammetry

- DELL workstation for Data Sciences.

- Lithic technology laboratory for the creation of a possible comparative collection (if necessary, within the scope of the presented project) and equipped with an extensive lithotheque.

- Transmitted and reflected light microscopes (if the presented project also involves the use wear analysis or the analysis of raw material procurement areas).

- Office, access to all online bibliographic resources, and a specialized library on prehistory. During the foreign mobility, at the Muséum national d'Histoire naturelle de Paris, additional equipment will also be made available.

- A KONICA MINOLTA RANGE 7Scanner, a measurement stand, a rotary table (acquisition and data processing software: RangeViewer and Geomagic Wrap).

- A Faro Edge ArmScanner from Faro, consisting of a measurement arm and a FaroBlu TM non-contact scanner (Geomagic Wrap software). This scanner is provided through a partnership with the NGO Global Digital Heritage.

- Access to the Distributed System for Scientific Collections (DiSSCo).

Collaboration networks involving the research team

The international network involving the research team has been partially described at point 12 and supported by the common projects listed at point 17.

The network of national collaborations underlying the research stems from partnerships with colleagues from various Italian universities where prehistoric studies are particularly developed: the "Sapienza" University of Rome for paleontological aspects, the University of Trento for geoarchaeology and the later phases of prehistory, the University of Modena and Reggio Emilia for paleoenvironmental studies, and the University of Benevento for studies on the mineralogical characterization of raw materials.

An important role will also be played by collaborations with prehistory museums with which the team of researchers works closely and has curated part of the exhibitions: Borgosesia Paleontological Archaeological Museum, Pirro Nord Museum in Apricena, Civic Museums of Modena, Vittorino Cazzetta Museum in Selva di Cadore, Sant'Anna d'Alfaedo Paleontological and Prehistoric Museum, Isernia La Pineta Paleolithic Museum.

The collaborative network also includes some private companies that can contribute to the development of this research by providing their expertise in parallel but fundamental areas. The innovative company "Archeosmart s.r.l." (Italy), a spin-off of the University of Ferrara, will contribute to the dissemination of results and their application in the context of museum outreach. The company "HolyMoka Games" (France) will contribute to the development of Python programming.

Moreover, the candidate will be integrated into a peer context thanks to the presence, within the PhD program in Human Sciences at the University of Ferrara, of other PhD students focusing on themes related to prehistory. Specifically, they will be accompanied by PhD students who apply geometric morphometrics to the study of the evolution of brain internal structures and by those studying the technological aspects of lithic industries.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

The main projects in which members of the research group are involved are (non-exhaustive list due to character limitations):

- 610531-EPP-1-2019-1-IT-EPPKA1-JMD-MOB Erasmus+: Key Action 1 EMJMD. GA 2019-1462 International master in Quaternary and Prehistory - https://quaternaryprehistory.eu/- PI: Marta Arzarello

- ANR (Agence Nationale de la recherche) – AAPG2019 – ANR-19-CE27-0011. NEANDROOTS. Understanding a threshold in Human evolution at 450-350 Ka through the roots of Neanderthal behavior - https://sites.google.com/unife.it/nenandroots/home - PI: Marie-Hélène Moncel, involved members: Marta Arzarello

- 2023-1-FR01-KA220-HED-000153092 KA220-HED - Partenariats de coopération dans l'enseignement supérieur HERIT-AWARE « AWAREness and management of natural and cultural HERITage challenges: a skill acquired during university studies » - PI: François Sémah, MNHN - PI of the Ferrara' Research Unit: Marta Arzarello

- R2STAIR EH2020-MSCA-COFUND-2020 Programme, Grant agreement ID: 101034349 - https://cordis.europa.eu/project/id/101034349 - PI: Carlos Lorenzo (URV), involved members: Marta Arzarello & Marco Peresani

- ERC Advanced Grant 2021 LATEUROPE - Why late earliest occupation of Western Europe? - https://cordis.europa.eu/project/id/101052653 - PI: Marie-Hélène Moncel, involved members: Marta Arzarello & Paula Garcia Medrano

- Ecole Française de Rome « L'Italie paléolithique : peuplement et traditions techniques » - https://www.efrome.it/it/la-ricerca/assi-di-ricerca – PI : Marta Arzarello & Marco Peresani

- COST Project "Integrating Neandertal Legacy: From Past to Present" - https://inealcost.inantro.hr/ - PI of the Ferrara Research Unit: Marco Peresani

- PRIN 2022 "AFTER THE ICE - Forager Uses of "Persistent Places" in the Late Upper Palaeolithic of the Circum-Adriatic Region: Perspectives from the Riparo Tagliente (Verona, Italy) and Badanj (Bosniaand Herzegovina)" – PI: Federica Fontana

Thematic Area 3 – Civil Security for Society

UNIVERSITÀ DI FERRARA (UNIFE)

Enhancing Risk Prevention in Society: Advanced Mathematical Methods and Computer Science Techniques

Doctoral Position

Enhancing Risk Prevention in Society: Advanced Mathematical Methods and Computer Science Techniques

Doctoral Programme

Mathematics

Description of the doctoral position's main topic

The PhD project will focus on developing advanced mathematical models and computer science tools for risk prevention in society, with a strong emphasis on leveraging big data techniques. This interdisciplinary project encompasses three main research themes: design of optimal response strategies, mitigating risk in epidemics, and prevention of cyber-attacks.

A first line of research encompasses the development of mathematical models and computational algorithms aimed at optimizing disaster response strategies. This includes but is not limited to, enhancing evacuation planning protocols, effectively allocating resources, and facilitating the coordination of emergency services. To achieve these objectives, stochastic optimization techniques such as consensus-based optimization (CBO) methods will be employed, leveraging their capacity to iteratively converge towards optimal solutions by aggregating information from multiple agents. Additionally, the use of machine learning approaches will play a pivotal role in capturing the complex dynamics inherent in disaster scenarios, enabling a more accurate representation of system behaviour.

The second direction of research involves the development of mathematical models to assess epidemic risk within communities, integrating principles of kinetic theory, epidemiology, and collective dynamics. This interdisciplinary approach aims to understand how disease transmission interacts with social connections, ultimately informing effective policy and control measures. By simulating various scenarios and interventions, the project will provide valuable insights into the spread of infectious diseases and the design

of efficient preventive measures. Such research contributes to evidence-based policymaking, enabling proactive strategies to mitigate epidemic risk and foster community-wide consensus on public health measures, thus enhancing overall disease control efforts.

The last research field considers the fact that modern industrial environments face not only the safety and security challenges arising from the convergence of Information Technology (IT) and Operational Technology (OT), but also the fact that there is no longer a single, enterprise-wide perimeter. To address such issues, one should analyze pros and cons of adopting in the industrial landscape the Zero Trust Architecture (ZTA), a strategy removing the assumption that connected devices within the enterprise borders should be trusted. The research will investigate the adoption of Next Generation Firewalls (NGFWs) and Digital Twins (DTs) in the edge-to-cloud continuum, also by defining and dynamically evaluating the trustworthiness of deployment environments.

The PhD project aligns with regional, national, and global efforts in disaster management, public health, and cybersecurity. It offers career opportunities in academia, government, and private sectors, focusing on enhancing societal resilience and security through interdisciplinary research.

Sub-themes of the doctoral position's main topic (if any)

None

Potential Supervisors

Lorenzo Pareschi, Giacomo Dimarco, Carlo Giannelli.

Doctoral candidate's desirable skills and competences

Scientific and technical skills

For the first and second research directions the candidate should have some familiarity with partial differential equations and some elementary course of numerical analysis. The knowledge of programming languages such as Matlab, Python or Julia (but C/C++ or Fortran can be used as well) will help the candidate to advance especially in the first research topic.

For the third line of research, while it is not required that the candidate has previous experience within the cybersecurity research field, it is a requirement a good knowledge about basilar aspects of operating systems, networking, web applications, programming, and Linux administration.

Description of the research group(s) in which the doctoral candidate will be integrated

The successful candidate will be hosted at the Department of Mathematics and Computer Science of the University of Ferrara and will be member of the Center for Modeling, Computing and Statistics (CMCS). The Department is a node of the Marie-Curie Doctoral Network DataHyking. In the following a brief description of the key members of the research group their main research interest and achievements. Lorenzo Pareschi is the Chair of Applied and Computational Mathematics at Heriot-Watt University, Edinburgh UK, and Professor of Numerical Analysis at the University of Ferrara. He obtained his Ph.D. in Mathematics from the University of Bologna. His primary research activities focus applied and computational mathematics, optimization, uncertainty quantification with a focus on hyperbolic and kinetic equations. He was recognized as a Nelder Fellow at Imperial College, London, UK, in 2015, a John von Neumann Professor at the Technical University of Munich, Germany, in 2019, and a Wolfson Fellow of the Royal Society in 2023. He is associate editor for several international journals, including Multiscale Modeling and Simulation and SIAM Journal on Scientific Computing. He has authored over 200 scientific publications and 5 books. Giacomo Dimarco received the Ph.D. degree in applied mathematics from the University of Ferrara. He is currently Professor in Mathematical Physics at the University of Ferrara. He was Assistant Professor at the University of Toulouse, France, from 2009 to 2013 and Associate Professor in numerical analysis from 2013 to 2021 in Ferrara. His primary research activities focus mathematical modeling, computational mathematics, kinetic theory, control and uncertainty quantification. He is Associate Editor of Journal of Computational Physics and Annali of the University of Ferrara. He is the Director of CMCS and next Director of the Department of Mathematics and Computer Science. Carlo Giannelli received the Ph.D. degree in computer engineering from the University of Bologna. He is currently an Associate Professor in computer science at the University of Ferrara. His primary research activities focus on Industrial Internet of Things, Digital Twin management, Software Defined Networking, Blockchain technologies, and cybersecurity in Industry 4.0. He serves on Editorial Boards of COMCOM and EURASIP JWCN. Carlo Giannelli is part of the Distributed Systems research group at the University of Ferrara, carrying out scientific research in various fields, such as Big Data, Cloud/Edge/Fog Computing, IoT in Industry 4.0 and Smart City environments, IT service management and opportunistic networking.

For more detailed information about the group's research activities and achievements, additional details can be found on the following web pages:

https://dmi.unife.it/en

https://www.unife.it/centri/centro/modeling-calculation-and-statistics-centre

https://ds.unife.it/

https://datahyking.eu

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The Department of Mathematics and Computer Science will provide all necessary equipment and computing resources necessary to conduct the research. In addition, the candidate will join the CMCS and the DTCS research teams.

CMCS is an interdepartmental research centre affiliated with the University of Ferrara, promoted by the departments of Mathematics and Computer Science, Economics and Management and Engineering. The centre involves several researchers from different Italian universities. The primary function of the CMCS is to carry out research in various disciplines, including applied mathematics, numerical analysis, scientific computing, computational fluid dynamics, machine learning and statistics. The final aim foresees the application of the scientific goals achieved to real and tangible problems, through the development and implementation of mathematical models and software. In addition, the centre is committed to organizing educational and public events, of a national and international nature, related to cultural, scientific, and technical innovation in the areas of expertise of the centre.

The Digital Twin and Cybersecurity (DTCS) research team (part of the Distributed System research team) at the University of Ferrara, aims at investigating, analysing, and experimentally validating Zero Trust techniques and the Digital Twin paradigm to prevent, identify, and counterattack cyber-attacks and cyber threats. The research DTCS team is focused on IoT devices and industrial environments, but the same solution can be validated within Smart Cities environments. In addition, the DTCS research team designs and develops innovative solutions aiming at exploiting the Blockchain technology in industrial environments, by exploiting state-of-the-art platforms such as Hyperledger Fabric, and by extending traditional solutions to provide innovative features, e.g., to allow the resiliency of industrial environments even if (partially) compromise by an attack.

Collaboration networks involving the research team

The applied mathematical group has established structural and ongoing scientific collaborations with prestigious international research institutions such as CNRS and INRIA, the University of Toulouse, Nice, Rennes in France, Aachen, Kaiserslautern in Germany, Oxford, Edinburgh in UK, Shanghai in China, Courant, Madison, and Washington University in USA. The computer science group has also established structural and ongoing scientific collaborations with prestigious international research institutions such as the Florida Institute for Human & Machine Cognition (IHMC) of Pensacola, FL, USA and IBM TJ Watson Research Center in New York, NY, USA.

The DataHyking network involves six partner universities (Leuven, Nice, Aachen, Kaiserlautern, Rome, Ferrara) and is a European Doctoral Network with the aim to create a data-driven simulation framework for kinetic models of interacting particle systems. DataHyking is focused on developing reliable and efficient simulation methods, designing robust consensus-based optimization, also for machine learning, and developing multifidelity methods for uncertainty quantification and data assimilation. Applications involve traffic flow, finance, and granular flow, also in collaboration with industry. The PhD candidate will be fully involved in the network events and scientific collaborations.

The DTCS research team is involved in the EU 6G Smart Networks and Services Industry Association (6G-IA) https://6g-ia.eu/, providing the perspective of EU industry and research institutions on the next generation of networks and services. Its main objective is to contribute to the EU's leadership role in research areas related to 5G, 5G evolution, Smart Network Service (SNS) and 6G. 6G-IA carries out a wide range of activities in strategic areas including standardization, research and development projects, technological expertise, collaboration with key sectors of industry vertical markets, for trial development and for international cooperation.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

The candidate will join the DTCS research team to actively participate in several active funded projects carried on together with several other Italian and international universities.

European Projects

- "DATAHYKING - Data-driven simulation, uncertainty quantification and optimization for hyperbolic and kinetic models", HORIZON-MSCA-2021-DN-01-01 - MSCA Doctoral Networks 2021. University of Ferrara, KU Leuven, Roma La Sapienza, INRIA, University of Nice, University of Kaiserslautern, RWTH Aachen University. Lorenzo Pareschi scientific responsible for University of Ferrara.

National projects

- "Advanced numerical methods for time dependent parametric partial differential equations with applications", MIUR-PRIN 2022 project, Lorenzo Pareschi responsible of local unit.
- "Integrated Mathematical Approaches to Socio–Epidemiological Dynamics". PRIN 2020, Giacomo Dimarco responsible of the Research Unit. PNRR Future HPC & BIG DATA. Participants of the unit of the University of Ferrara.
- "IntelliGent and secure Networking in IndusTrial Environments: towards Industry 5.0 – IGNITE 5.0", PR-FESR 2021-2027 Regione Emilia Romagna, Carlo Giannelli responsible of local unit.
- "Cyber range for industrial security - CRI4.0", PR-FESR 2021-2027 Regione Emilia Romagna, Carlo Giannelli responsible of local unit.
- "Cybersecurity for Smart Industry - C4SI", PR-FESR 2021-2027 Regione Emilia Romagna, Carlo Giannelli responsible of local unit.
- "DATRUST - Connecting the physical and DigitAl worlds through TRUSTworthy dataflows", PRIN 2022 PNRR, Carlo Giannelli responsible of local unit.

UNIVERSITÀ DI PARMA (UNIPR)

Spin Systems for Quantum Technologies: advanced computing techniques, new concepts and realistic material simulations

Doctoral Position

Spin Systems for Quantum Technologies: advanced computing techniques, new concepts and realistic material simulations

Doctoral Programme

Physics

Description of the doctoral position's main topic

Quantum computation (QC) is among the most rapidly growing technological fields, with the potential to greatly outperform existing computers on specific tasks. Spins represent prototypical quantum systems, and are the simplest objects where quantum mechanics can be framed and numerically simulated. In the context of quantum technologies, spins in solid-state systems are natural candidate elementary units (qubits) because of their relative decoupling from the environment and of their integration in a solid-state matrix, which eliminates the need to trap them optically or electromagnetically. Besides single spins, collective degrees of freedom resulting from coupled spins in nanostructures can be used to encode qubits or multi-level units (qudits). In particular, crystals of magnetic molecules are an excellent example, where the structure is chemically engineered in a bottom-up approach at the level of synthesis and whose properties can be changed to fit specific purposes. An alternative, or complementary, top-down approach is to assemble individual atomic or molecular spins on a surface, and control them by tips or external fields.

The candidate will exploit advanced computing techniques targeting many different aspects of such nanostructures which are relevant to their exploitation as elementary units of digital QC. These may include:

- The characterization of the Hamiltonian (e.g., ab-initio computational techniques like state-of-the-art density-functional-theory, DFT).

- The characterization of environment-induced decoherence due to phonons and/or nuclear spins (e.g., ab-initio DFT techniques; DFT-based machine learning force fields for spin-phonon couplings; large-scale simulations for systems of differential equations describing the open-system dynamics).
- The design of quantum control schemes –typically based on pulse sequences or quantum-circuit setups- driving the spins to perform specific tasks in quantum technologies, like quantum simulations or sensing (e.g., optimization of pulse sequences by conventional or machine-learning techniques, large-scale numerical simulations of the driven open-system dynamics).

The research will be carried out in the framework of many established connections with international groups. These include theoretical physicists (ab-initio calculations and quantum algorithms), chemists (synthesis of new molecules) and experimental physicists (characterization of the modeled systems and actual implementation of quantum algorithms). See below for more details.

At the end of the project the candidate will have acquired a solid background in digital quantum technologies and in large-scale computational techniques. Quantum technologies are a rapidly developing field, thus career opportunities will exist both within the academic and industrial sectors. The demand for specialists is quickly growing: almost all universities in the world have started or will soon start research and teaching activities on these topics, and many new corporate actors in the field are constantly emerging, ranging from small start-ups to large corporations. In addition, the significant competences in mathematical modeling and large-scale computations are a precious transversal skill which is highly-valued in a very broad range of companies.

Sub-themes of the doctoral position's main topic (if any)

None

Potential Supervisors

Paolo Santini, Alessandro Chiesa, Elena Garlatti

Doctoral candidate's desirable skills and competences

Scientific and technical skills

Very good knowledge of quantum mechanics, good programming skills, and a good knowledge of physics of matter

Description of the research group(s) in which the doctoral candidate will be integrated

The Spin-based Quantum Science group of the University of Parma has a consolidated activity on developing theoretical models for the quantum behaviour of spin systems at the atomic, molecular and supra-molecular level, and on their potential applications in quantum technologies, particularly quantum computation and simulation. Most of this research is carried out through the identification of suitable model hamiltonians for physical systems encoding qubits, the numerical simulation of the associated quantum behavior, and the design and optimization of control schemes inducing the desired dynamics, both in closed- and open-system setups. Hamiltonians and system-environment interactions for potential candidate qubits/qudits are obtained through information from ab-initio calculations, and from the interpretation of targeted experiments. Calculations are typically large-scale for the systems of interest. In addition, the group has a proprietary NMR laboratory where some of the control schemes mentioned above can be experimentally implemented and tested. The group has 17 members, including 4 permanent staff, and a large number of international collaborations. The group has obtained funding from several international and national competitive projects in the last years. For more detailed information about the group's research activities and achievements, additional details can be found on the following web pages: https://www.spinquantumscience.unipr.it/.

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

Computational facilities: dedicated workstations, high-performance-computing cluster of the University of Parma https://www.hpc.unipr.it/dokuwiki/doku.php?id=calcoloscientifico:userguide, high-performance computing facility at Cineca https://www.cineca.it/en/hpc, Jülich supercomputing center https://www.fz-juelich.de/en/ias/jsc. Experimental facilities: proprietary NMR laboratory https://www.spinquantumscience.unipr.it/about-us/nmr-quantum-lab/328/.

Collaboration networks involving the research team

The research team has a large number of collaborations with highly recognized international groups. These include theoretical physicists (ab-initio calculations and quantum algorithms), chemists (synthesis of new magnetic molecules), and experimental physicists (characterization of the modelled systems and actual implementation of quantum algorithms). We mention among the Theoretical physicists: E. PAVARINI

(Forschungszentrum Jülich), A. LUNGHI (U. Dublin), I. TAVERNELLI (IBM Zurich), S. WIMBERGER (U. Parma), D. ZUECO (U. Zaragoza); Chemists: A. PAINELLI (U. Parma), R. SESSOLI (U. Florence), R. WINPENNY (U. Manchester); Experimental physicists: R. BITTL (FU Berlin), L. DA COSTA PEREIRA (KU LEUVEN), F. LUIS (CSIC Zaragoza), M. WASIELEWSKI (Northwestern U.).

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

European Projects

- "CASTLE (Chirality and Spin Selectivity in Electron Transfer Processes: from Quantum Detection to Quantum Enabled Technologies, Horizon Europe, GA 101071533). ERC-SyG, PI Stefano Carretta (Uni Parma). Role of the research team in the project: theoretical modeling, DFT calculations, numerical simulations, design of experiments on real systems, design of schemes of quantum technologies, NMR experiments.

- "Coherent addressing of isotopically pure lanthanide complexes by photons and efficient quantum error correction for Quantum Information Technologies". Novo Nordisk Foundation, grant NNF21OC0070832, call "Exploratory Interdisciplinary Synergy Programme 2021". PI: Stergios Piligkos (Uni Copenaghen), co-PI Stefano Carretta (UNIPR). Role of the research team in the project: theoretical modeling, numerical simulations, design of experiments on real systems, design of schemes of quantum technologies NMR experiments.

National projects

- NQSTI, National Quantum Science and Technology Institute. Consortium of universities and industries funded by the National Recovery and Resilience Plan, PI for Uni Parma Stefano Carretta (UNIPR). Role of the research team in the project: theoretical modeling, DFT calculations, numerical simulations, design of experiments on real systems, design of schemes of quantum technologies, NMR experiments.

- CROQUET (Molecular Dimers for Quantum Error Correction on the surface, PRIN national project). PI Lorenzo Poggini (CNR-ICCOM), co-PI Elena Garlatti (UNIPR). Role of the research team in the project: theoretical modeling, numerical simulations, design of experiments on real systems, design of schemes of quantum technologies NMR experiments.

UNIVERSITÀ DI BOLOGNA (UNIBO)

Combining Machine Learning and Computational Chemistry to explore the chemical space of functional materials

Doctoral Position

Combining Machine Learning and Computational Chemistry to explore the chemical space of functional materials

Doctoral Programme

Industrial Chemistry

Description of the doctoral position's general/main topic

The proposed project will necessarily aim at combining computational chemistry (CC) to artificial intelligence / machine learning (ML) on target energy-related applications concerning photoactive organic materials (see subthemes) with a focus on the production and management of large amount of data (BD). Creating new molecules according to specific functional requirements has been the dream of chemists and industries for decades. Today, with the improvements of first-principle packages, AI, and hardware, this might be possible. The future of material research is for molecules to be pre-designed on a computer for fitting a specific purpose, more than checking their chemical-physical properties and then finding a role for them.

The challenges and the benefits of the approach have been nicely reviewed by Tkatchenko and coworkers (https://doi.org/10.1021/acs.chemrev.1c00107):

1. Reliance on ML in CC algorithms must be increased:

2. More general ML approaches are needed

3. ML representations must include the right physics

4. CC + ML applications need to strive toward achieving realistic complexity

5. Much more comprehensive data sets (BD) need to be assembled and curated

6. Bolder and deeper explorations of chemical space (BD) are needed.

The successful applicant is expected to contribute to the progress of the field along all these directions.

Just to make a few, non exhaustive examples, possible activities could be the development of:

1. digital platforms for the computational design of a certain class of molecules

2. AI-based generator models capable of cleverly proposing new molecular structures exploring the full chemical space of the targeted compounds.

3. automated workflows to predict with computational chemistry methods the physical properties of different candidate molecules in gas and liquid phase, and in solution.

4. automated algorithms for interrogating (data-mining) existing computational materials repositories (see e.g. https://cmr.fysik.dtu.dk/ https://docs.iochem-bd.org/ https://next-gen.materialsproject.org/ https://www.materialscloud.org/home https://cpd.chemcatbio.org/ https://www.catalysis-hub.org/ https://opencatalystproject.org/) or literature sources.

5. descriptors and standards for the representation of the chemical data, i.e. the database design.

These developments will be of interest for introducing digitalization (Industry 4.0) in several business sectors at the interface between chemistry, energy, and engineering, such as chemical companies implementing computational solutions for molecular design, and manufacturers producing and marketing the target technologies. Moreover, the project will advance the European scientific basis, and fostering its leadership and global role in the area of renewable energy, in this way supporting EU goals for climate protection, energy independence and economic growth.

Sub-themes of the doctoral position's main topic (if any)

We singled out three possible subthemes / application fields which are of great interest for the researchers of the department of industrial chemistry:

1) Molecular solar thermal fuels (https://doi.org/10.1016/j.joule.2021.11.001): MOSTs are photoswitchable molecules that can store the energy from the sun ("Solar-to-X") and deliver it back as heat in a reversible way. These systems, upon light absorption, can interconvert from a thermodynamically stable isomer A into a higher energy metastable isomer B. The thermal or catalytic B->A back-conversion process can release a certain amount of heat (the energy difference between A and B photoisomers). If this heat release can be controlled, it can be exploited in several technologies, for instance for domestic heating, however materials and devices need further development to meet market requirements and the efficiency range achieved by current solar cells.

2) photoactivated artificial molecular motors (https://doi.org/10.1021/jacsau.3c00089): Here the focus, rather than in storing chemical energy for a later release, is the accurate control of long-range motion at the

molecular scale, which holds great but still unfulfilled potential for the development of ground-breaking applications in energy storage and bionanotechnology.

3) organic photoredox catalysis (https://doi.org/10.1021/acs.chemrev.6b00057): photocatalysis has become a powerful strategy for constructing extensive collections of biologically relevant molecules and complex natural products. Additionally, combining photocatalysis with other catalytic methods has provided novel transformations in the arsenal of organic and industrial chemistry. However, much work remains in developing photocatalysts with higher stability, activity, and performance, including exploring (or avoiding) metals and metal–ligand combinations, as well as novel organic chromophores.

Potential Supervisors

Luca Muccioli, Ivan Rivalta, Marco Garavelli, Artur Nenov

Doctoral candidate's desirable skills and competences

- Computational skills and a passion for computer science and modelling are a must, as the PhD will involve a significant amount of coding (mostly in Python).
- -experience in high performance computing and in ML/AI methods
- familiarity with basics of mainstream programming languages (e.g., C/C++, Fortran9X, Java, Python)
- -experience in molecular modelling
- good communications skills, scientific curiosity, and interest in interdisciplinary research

Description of the research group(s) in which the doctoral candidate will be integrated

The SC2 group specializes in Computational Photochemistry, Photophysics and Spectroscopy of Photoresponsive Molecular Materials, and Computational Materials Science. This includes i) the development and application of computational tools for modelling accurate photoinduced dynamics of complex photoresponsive molecular systems in realistic conditions, including their underlying multi-pulse transient spectroscopies at various spectral regimes, spanning the NIR-VIS-UV-Xray spectral window ii) the characterization and analysis of photoactive molecular materials (from simple isolated molecules to biological photoreceptors and complex molecular architectures including environment effects) is employed for the design of novel and smart materials (e.g., photochromic systems, molecular switches, etc.) with tailored properties, encompassing a tunable photophysics and a controlled (photo)reactivity. iii) the prediction of structural, electronic, and chemical properties of functional materials, including organic soft

matter, biological systems and catalysts, through computer simulations (Molecular Dynamics, Metropolis and Kinetic Monte Carlo) methods, quantum chemistry calculations and network analysis.

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The computational chemistry group provides the required expertise of an array of quantum and classical calculation and simulations techniques, in computer programming, and the computational resources. The local computer center, fully dedicated to the computational chemistry unit, hosts most recent HPC clusters (~2000 cores) and computational chemistry software (Gaussian, Molcas, Molpro, Amber, NAMD, VASP, QuantumEspresso, etc.).

Collaboration networks involving the research team

The group has established collaborations with the local experimental groups listed below, to not mention a large network of national and international collaborations:

- Center for Light Activated Nanostructures https://centri.unibo.it/clan/en
- Organic Catalysis Structural Analysis https://site.unibo.it/organic-catalysis-structural-analysis/en
- Catalysis for Renewable and Innovative Process "Care in Process" group: https://site.unibo.it/catalysis-for-renewables-and-innovative-processes/en
- Center for Chemical Catalysis https://centri.unibo.it/c3/en

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- GEM – GEtting the MOST out of the sun – IFAB foundation project https://www.ifabfoundation.org/ifab-activities/projects/gem-getting-the-most-out-of-the-sun/ PI Luca Muccioli
- SimDOME – Digital Ontology-based Modelling Environment for Simulation of materials – H2020. https://simdome.eu/ PI Marco Garavelli

UNIVERSITÀ DI BOLOGNA (UNIBO)

Big Data handling in Next-generation Particle and Astroparticle Physics Experiments

Doctoral Position

Big Data handling in Next-generation Particle and Astroparticle Physics Experiments

Doctoral Programme

Data Science and Computation

Description of the doctoral position's main topic

The Particle Physics and Astroparticle Physics program has achieved major advancements in fundamental physics, technology, and design of innovative computational tools and algorithms, resulting in landmark discoveries like the first observation of the Higgs boson at CERN in 2012 and the first detection of gravitational waves by LIGO and Virgo in 2015/2016. Future challenges require innovative software and computing solutions towards the physics mission.

Using CERN as an example, computing operations are managed through the Worldwide LHC Computing Grid (WLCG) project, a global collaboration spanning 170 computing centres across 40 countries. WLCG aims to provide global computing resources for storing, distributing, and analysing approximately 200 PB of LHC data annually. The High-Luminosity LHC (HL-LHC) project, a top priority since 2013, is slated to start in 2029, significantly increasing collision rates and enabling potential discoveries. For instance, HL-LHC is projected to produce a minimum of 15 million Higgs bosons yearly.

Significant investments are being made in experimental communities to prepare for the upcoming challenge. This includes enhancing the data acquisition pipeline to handle a broader range of collision events, as proton-proton collisions produce a diverse array of particles at a rate of 40 MHz. These events are tracked by radiation-hardened detectors and processed through multi-step "trigger" systems designed to rapidly select or reject data. Data collection throughput is crucial for identifying potentially significant signatures with confidence, a necessity that will only grow with the advent of HL-LHC.

The project of work of a COFUND "Futuredata4EU" scholarship will focus on software and computing tools as enabling technologies for extraction of insight from Big Data, towards an increased capacity to trigger and record relevant data, hence facilitating the currently needed improvements to LHC data collection in Run-3, with the mindset to also look forward to future data collection needs, i.e. contribute to the following HL-LHC phases as well as providing critical insight to develop future detectors and data flows for even more ambitious objectives e.g. in the Future Circular Collider (FCC) and in the Einstein Telescope (ET) for gravitational waves detection, currently in their Feasibility Study phases.

Among the lines of work foreseen in this PhD project, the following can be mentioned:

- improve ML-assisted data collection (including simulations) and better leverage available (and new) computing infrastructures;
- develop data-driven, improved and accelerated algorithms and techniques (including AI-based) to filter out uninteresting events and filter in exotic interesting signatures at high speed and efficiency;
- contribute to the design and implementation of innovative AI-powered real-time processing workflow, with the ambitious goal to analyse every single collision produced in large-scale data-intensive experimental settings.

Sub-themes of the doctoral position's main topic (if any)

None

Potential Supervisors

Daniele Bonacorsi; Felice Pantaleo; Andrea Bocci

Doctoral candidate's desirable skills and competences

Scientific and technical skills

- Familiarity with main concepts in experimental particle and/or astroparticle physics
- some experience in data acquisition and/or data analysis techniques
- programming skills, particularly in languages such as C++ and/or Python
- familiarity with statistical methods and machine learning frameworks
- ability to work effectively and independently in a collaborative research team
- excellent written and verbal communication skills.

Other skills

- previous involvement in large-scale experimental projects or collaborations
- advanced knowledge of experimental particle physics and/or astroparticle physics
- demonstrated experience with specific data handling tools and frameworks
- knowledge of distributed computing systems and parallel processing techniques
- familiarity with GPU programming and HPC systems

Description of the research group(s) in which the doctoral candidate will be integrated

D. Bonacorsi is Full Professor in Experimental Physics at University of Bologna, working over the last 20 years on High Energy Physics (HEP) experiments at CERN. His research interests expanded to the design, deployment and operations of large-scale Software and Computing systems for data-intensive science. In the LHC community, he has been Offline and Computing coordinator for the CMS experiment at the LHC, he collaborates with major Data and Computing Centres in EU, US, Asia, and he has been among the pioneers of Machine/Deep Learning solutions in the HEP community. Dott. F. Pantaleo and Dott. A. Bocci are CERN staff scientists, have been covering leading roles in the Trigger of the CMS experiment at LHC since more than a decade, and in the adoption of deep learning techniques in CERN experiments, and are now deeply involved in designing and developing advanced solutions for next-generation triggers in HEP. The research group is complemented at University of Bologna by Dr. Carlo Battilana and Prof. Alessandra Fanfani, who are researchers with advanced software skills and ability to work in large collaboration on physics analysis, trigger studies and computing activities, by Dr. Tommaso Diotalevi, currently a NRRP-funded (National Recovery and Resilience Plan) RTDa researcher involved in physics-serving technology advancements and computing infrastructures, and a set of PhD researchers enrolled in the "Physics" PhD and in the "Data Science and Computation" PhD at University of Bologna. All UniBO colleagues listed above have a standing affiliation with the Italian INFN funding agency for HEP research, and all senior colleagues listed above have a demonstrated records of mentoring Bachelor and Master students, as well as PhD and postdoc researchers. The selected PhD candidate will be based in Bologna, although frequent visits to CERN as well as extended period of secondment at CERN or in other collaborating institutions is foreseen throughout the duration of the PhD programme. The research group is committed to maintaining an open and collaborative work environment that stimulates professional and personal growth of all members, and to fostering a diverse and inclusive research environment that welcomes individuals of all genders and ethnicities.

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The PhD candidate will have access to the research facilities of the DIFA department, and - for computing needs - to local CPU and GPU farms, both experiment-specific and multi-experiment, including the resources dedicate to the future astro-particle Einstein Telescope project.

The PhD candidate will be considered for affiliation to a CERN experiment, hence becoming a CERN user, able to access the CERN research facilities.

The PhD candidate will be supported to have access to the computational resources offered by NRRP-funded (National Recovery and Resilience Plan) national initiatives such as the "National Centre for HPC, Big Data and Quantum Computing" and the "Future AI Research" (FAIR) partnership.

If required and relevant, the PhD candidate will be supported to prepare a dedicated ISCRA project with the CINECA supercomputing centre, located in the Bologna Technopole, to take advantage of the high-performance computing facilities of the Leonardo supercomputer.

The overall area of the Bologna Technopole will offer additional chances for interdisciplinary collaborations on advanced technology research around Big Data challenges with colleagues from a variety of diverse disciplines and on a vast set of topics and applications - ranging from weather forecast to smart mobility solutions, from energy efficiency to hardware-oriented research, from digital twins to quantum computing research.

Finally, the Bologna Technopole will also offer a stimulating environment to be in contact with SMEs of the Emilia Romagna region, complementing the academic research with potential collaborations with industrial partners on topics of common interest, which will expand and fertilise the personal vision and professional skills of the PhD candidate.

Collaboration networks involving the research team

The research team involving the FutureData4EU doctoral candidate is deeply embedded within extensive research collaboration networks, providing substantial added value to candidates. These networks span across academia and international research institutions, computing centres and data centres in Europe, US and Asia, in the network created by the World-wide LHC Computing Grid, fostering a rich environment for research collaborations and knowledge sharing. Within academia, in particular, our team collaborates closely

with renowned universities and research institutes worldwide, offering candidates opportunities for collaborative research, joint publications, and access to diverse expertise. This academic collaboration network facilitates exposure to cutting-edge research methodologies and enables candidates to engage with leading scholars in the field. Furthermore, strong ties in the Bologna Technopole with industry partners ensure that candidates gain practical insights into real-world applications of data science and Big Data challenges and solutions.

Overall, the collaboration networks involving our research team will provide the FutureData4EU doctoral candidates with a unique and enriching research experience, as candidates will have the opportunity to leverage these networks to expand their knowledge, develop valuable skills, and make meaningful contributions to the field on both a local and global scale.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year
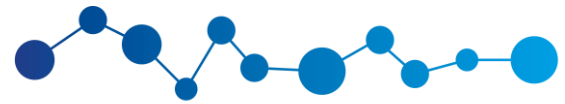
Internationally, the PhD candidate will be connected to large-scale CERN experiments and all related EU/US/national projects.

Nationally, the PhD candidate will be connected to NRRP-funded (National Recovery and Resilience Plan) initiatives, namely:

- "National Centre for HPC, Big Data and Quantum Computing", Mission 4, "Istruzione e Ricerca", Component 2, Investment 1.4, funded by the European Union - NextGenerationEU with an overall budget of about 320 MEuros, steered by the ICSC Foundation, whose President is Prof. Antonio Zoccoli (also INFN President and Full Professor at the University of Bologna)
- "Future AI Research" (FAIR) partnership, Mission 4, "Istruzione e Ricerca", Component 2, Investment 1.3, funded by the European Union - NextGenerationEU, with an overall budget of about 115 MEuros, which has WP whose activities are based in Bologna, with Prof. Michela Milano (Full Professor at the University of Bologna) as PI.