Hydromechanical coupling in tectonic faults and the origin of aseismic slip, quasi-dynamic transients and earth**quake** ruptures

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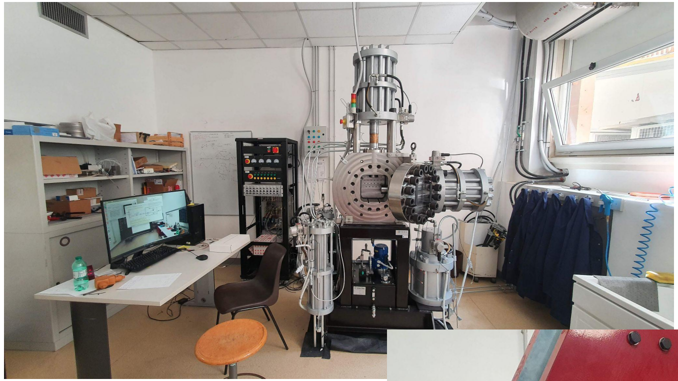
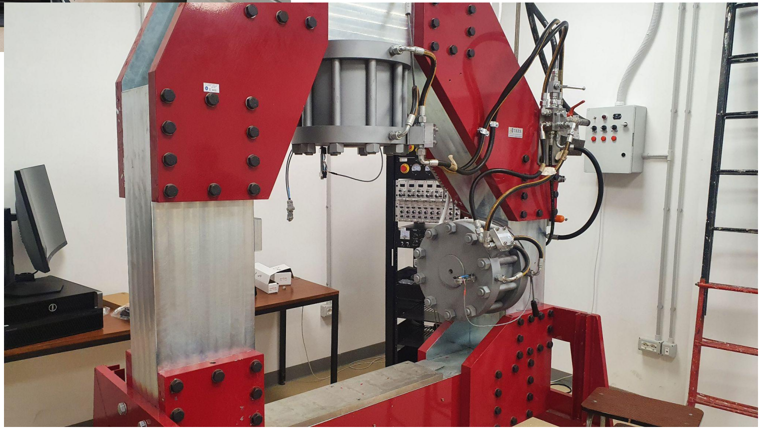
What do I do?

Sapienza

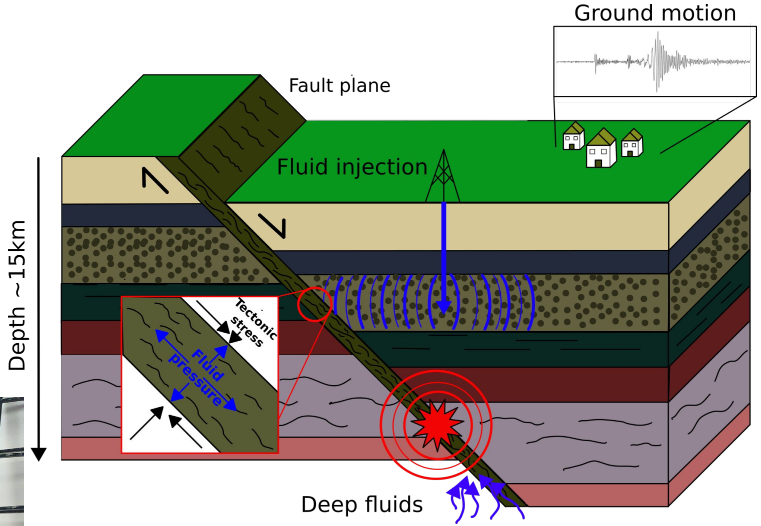
Rock Mechanics and earthquake physics lab

I am an experimental geophysicist





Prototype rock mechanics apparatuses to study the physics of earthquakes



Before the ERC

2014 PhD The Pennsylvania State University (PA, USA)

2015-2017 IF Marie Sklodowska-Curie Action

2017-2018 Post-Doc sponsored by TOTAL

2018-2021 RTD-B

Before the ERC

38 Peer reviewed articles – 1109 citation – H-index 20 (source Scopus)

10 invited talks at international meetings (3 AGU, 1 EGU)

(**2018**) European Geoscience Union Outstanding young scientist award, EMRP section

(**2020**) American Geophysical Union Early career award, MRP section

nature COMMUNICATIONS

ARTICLE

Received 4 Nov 2015 | Accepted 19 Feb 2016 | Published 31 Mar 2016 DOI: 10.1038/ncomms11104 OPEN

Laboratory observations of slow earthquakes and the spectrum of tectonic fault slip modes

nature geoscience LETTERS

PUBLISHED ONLINE: 8 AUGUST 2016 | DOI: 10.1038/NGEO2775

Precursory changes in seismic velocity for the spectrum of earthquake failure modes

nature COMMUNICATIONS

ARTICLE

https://doi.org/10.1038/s41467-020-15093-3 OPEN

Slow-to-fast transition of giant creeping rockslides modulated by undrained loading in basal shear zones

SCIENCE ADVANCES | RESEARCH ARTICLE

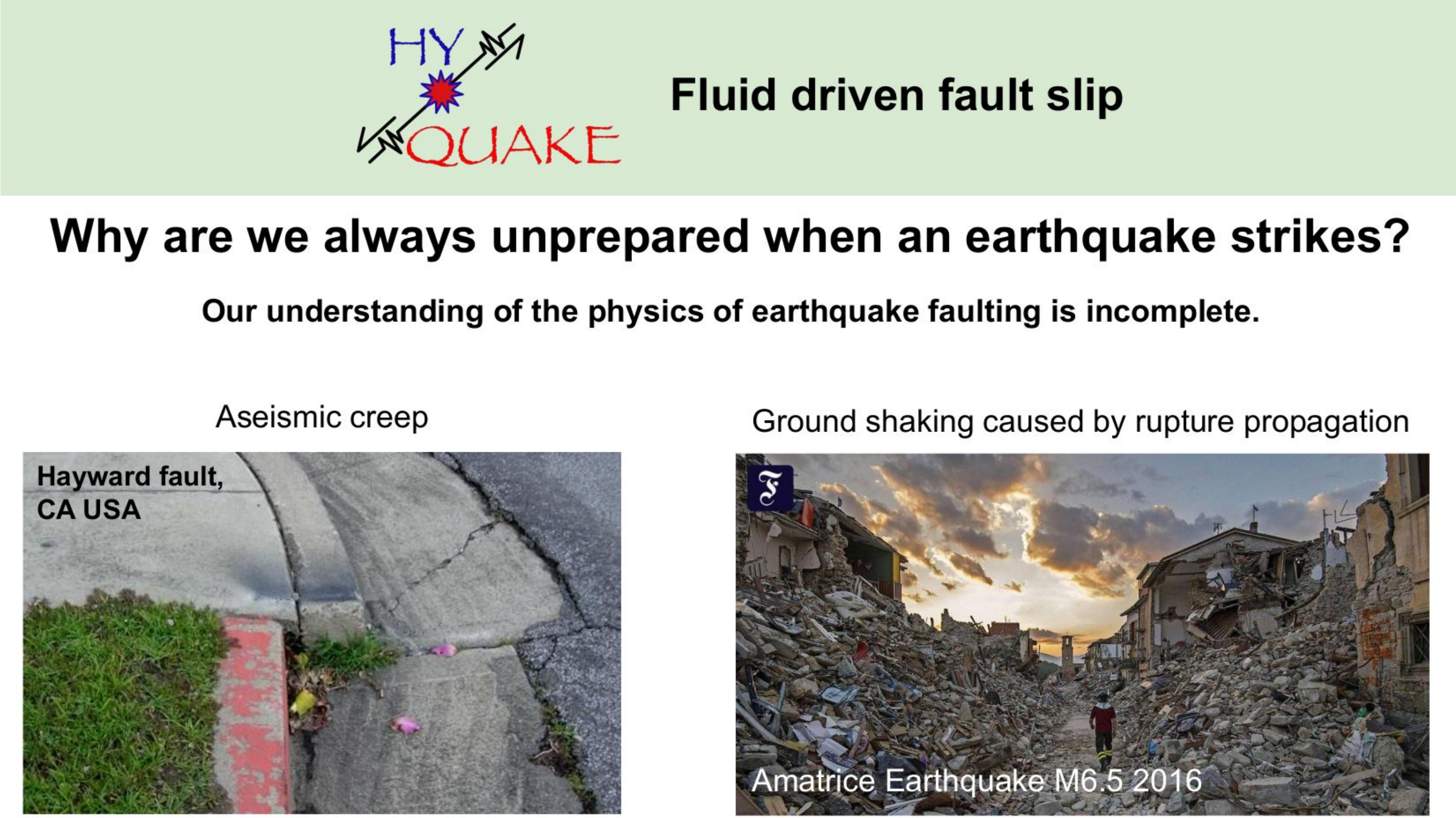
GEOPHYSICS

Stabilization of fault slip by fluid injection in the laboratory and in situ

THE GEOLOGICAL SOCIETY OF AMERICA®

Evolution of shear fabric in granular fault gouge from stable sliding to stick slip and implications for fault slip mode

THE IDEA



Opening slide of the interview

THE IDEA

State-of-the-art

Fluid induced seismicity is understood using over simplified friction laws

Paucity of data that document fluid driven fault slip

HYQUAKE will bridge the knowledge gap

… toward interpreting earthquake precursors

problem set slide of the interview

WRITING THE GRANT - B1

Scientific challenges of HYQUAKE

The soul of HYQUAKE is inter- and multi-disciplinary, combining experimental rock physics, seismology, material science and data science to build a novel and innovative understanding of the physical processes at the origin of fluid driven fault slip leading to earthquake rupture. I believe that there are some fundamental questions that need to be addressed:

(1) How do faults slip when driven by fluid pressure? *(related to WP 1)*

To address this question I need to push the technical boundaries of experimental rock physics to reproduce at best the natural P-T boundary conditions under which fluids and fault slip operate. The ability to perform laboratory experiments and measure frictional rheology in a way that illuminates the underlying mechanism at play during fluid induced fault slip is an essential prerequisite for developing truly operational models to understand the seismic risk.

(2) **How does fault zone structure evolution control fluid distribution during fault slip? *(WP2)***

This is a strategic area waiting to be characterized, at the interface between rock mechanics, microtectonics, seismology and fluid flow processes. To validate theoretical models that predict fluid distribution and slip stability within faults we need to understand the intimate relationship between fault zone structure evolution in space and time and permeability anisotropy (i.e. parallel and perpendicular to the shear direction). By measuring the concomitant evolution of fault microphysical processes (i.e. porosity changes due to dilation/compaction) and the fluid pressure distribution (i.e. permeability anisotropy) I will address their effect on the macroscopic (resulting) rheological properties.

(3) How can we predict the stress state on a fault during the seismic cycle? *(WP3)*

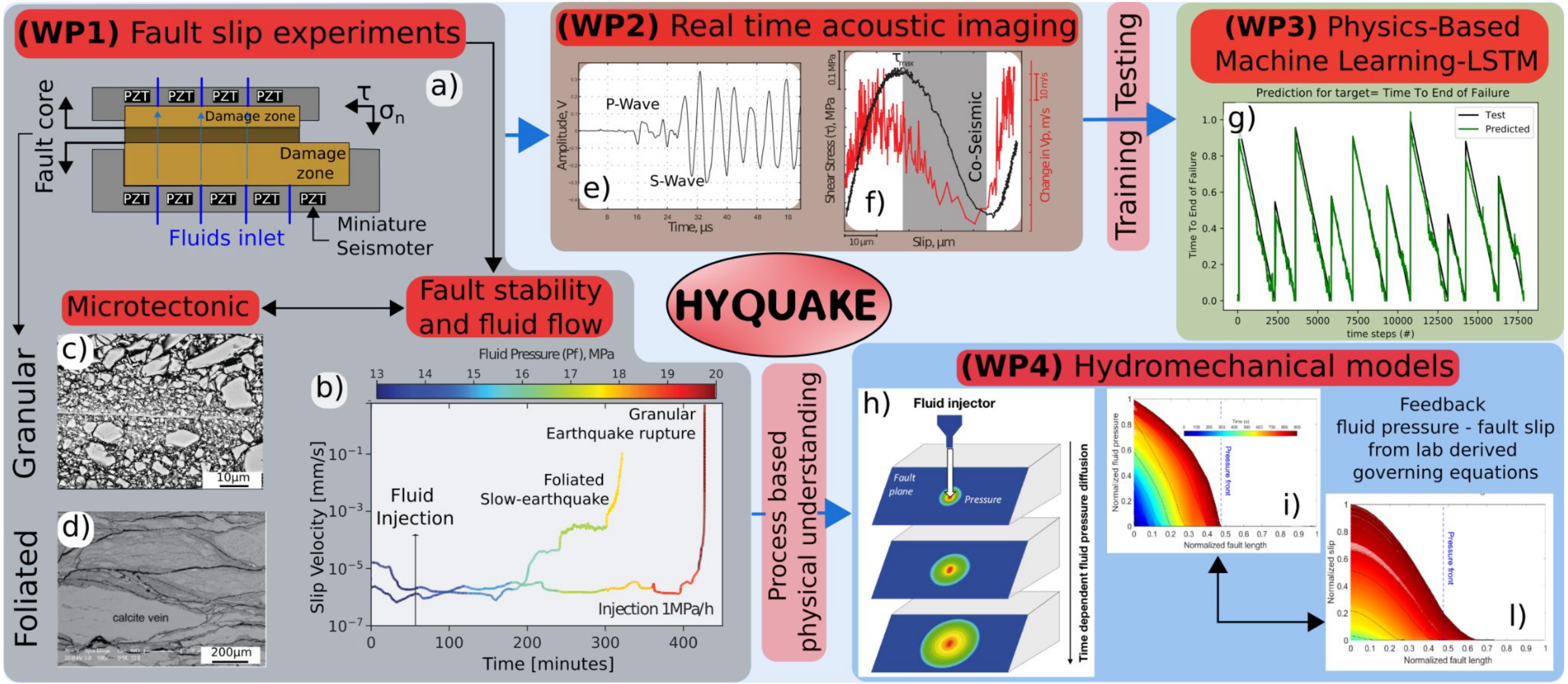
The seismic observation of natural faults has recently revealed that there is an intimate coupling between fluids and stress that is at the root of a rich spectrum of faulting behaviour (60-64). Fine tuned tomography studies have also shown that fluid migration is a fundamental component in the earthquake nucleation and aftershock distribution (e.g.,3,4). Developing new acoustic experimental techniques to image the hidden interaction between fluid pressure and fault motions that arise from the microphysical processes of strain localization is a major challenge that will allow the validation of theoretical concepts. Using these non-destructive, process based, acoustic signals (i.e. P- and S-wave velocity, Vp/Vs ratio and acoustic transmissivity) to train physics-based machine learning algorithms will give, for the first time, a tool to predict the time to failure of tectonic faults and retrieve constitutive relations for faulting.

(4) How does fluid pressure affect the size of an earthquake? *(WP4)*

This is a timely problem in geophysics for mitigating the seismic hazard. The up-scaling of physical processes identified in laboratory experiments to applications in natural systems is a strategic issue for anticipating crustal processes. Based on physical concepts inferred from unique laboratory experiments coupled with 3D hydromechanical models I can open the door to predict the in-situ behavior of fluid pressurized faults from tens to hundreds meter scale. These new findings will open the avenue for the development of physically based predictive models quantifying fluid pressure diffusion, aseismic slip, earthquake triggering, and the space-time evolution of seismicity at the crustal scale that are fundamental to improve our understanding of the seismic hazard.

WRITING THE GRANT - B1

Scientific challenges of HYQUAKE



Synoptic diagram for the B1

Evaluation step 1

Subject: Initial information on the outcome of the evaluation of proposals submitted to the Call for Proposals ERC-2021-STG - Proposal n° 101040600 HYQUAKE

Dear Applicant,

I am pleased to inform you that the ERC evaluation panels, composed of independent experts, have favourably reviewed your proposal in Step 1 of the evaluation process. We cordially invite you to attend an interview with the evaluation panel.

Date:	The video-conference interviews for your panel will take place from 11/10/2021 to 15/10/2021. Please make sure to keep these days free.
Evaluation panel:	PE10
Interview content:	Interviews will last between 20 and 30 minutes. They will include a short presentation by the applicant and time for questions and answers. The panel meeting will be organised fully remotely.
Link to add your phone number:	https://ec.europa.eu/eusurvey/runner/ERCSTG2021_phone_numbers_PEdomain

The INTERVIEW

Format: 3 minutes for a presentation and 22 minutes of questions

The INTERVIEW

Format: 3 minutes for a **presentation** and 22 minutes of questions

The INTERVIEW

Format: 3 minutes for a presentation and 22 minutes of **questions**

PI, Team and host institution

- Will you be able to manage 1.5 M Euros of budget and interact with your host institution?
- Why should we give you 1.5M euros?
- Have you got a management ability?
- Will you be able to coordinate your team members made of several professors?
- Will you be able to manage this multidisciplinary research?
- Which are the high-gains of your research?
- How is your ERC different from the ERC TECTONIC already going in your institution
- How this project will contribute to your scientific independence?
- Why can't you attain the independence without this project?
- Can't you find funding in Italy?
- What is the benefit that the EU will have from the project?
- Is it possible to predict earthquakes?
- the % of success of HYQUAKE?
- What is the contingency plan if something goes wrong?
- Would you be able to obtain the same results without the ERC ?
- What is the most innovative aspect of the research compared to the state of the art?
- Which two sentences do you hope will be added to a textbook thanks to your ERC?
- Where do you want to be in 5 years?
- Who are your main competitors?
- Who are your main collaborators?
- Why is this work best carried out at your Host Institution, and not e.g. in the USA,...?
- Describe your team and your recruiting strategy
- What is your strategy for selection of collaboration partners, e.g. with competitors?
- Expertise in area X/method Y seems to be missing in your project...?
- Your interaction with other ERC grant holders at the institution?
- What are your main achievements so far?
- Why will the ERC Grant be crucial for you at this stage?

The project

- What would you do if equipment X/PostDoc Nr. 2 were not funded by the ERC? (It should be clear from your answer that this would limit the impact of your project as you have carefully planned your budget; you would apply for alternative funding sources,...)
- What is unique about your project / Originality and ground breaking nature
- why is your project timely
- Validation of project results: How will you know that you have succeeded? How will you interpret results? E.g. statistical power analysis,...?
- What is the key risk of the project? How do you deal with it, what is your plan B?
- What is your focus now, what are your priorities?
- Would this research not better be funded by industry?
- How do you use the rest of your working time?
- What are milestones/intermediate goals of your project?
- Who is going to develop numerical models and machine learning algorithms?
- What about the scale-dependence of the physical processes?
- What is the difference between creeping and locked and fast/slow earthquakes?
- How do you upscale laboratory results to nature?
- you are mainly an experimentalis, will you be able to develop models?
- What do you mean with anticipate earthquakes?
- How do you bridge the gap between friction and fluids?

Final Evaluation

European Research Council
Scientific Council
Established by the European Commission

ERC/ML/2021

Dear Applicant,

Thank you for your application for an ERC Starting Grant.

Over 4000 proposals were submitted to this call and the evaluation panels were impressed with the high quality of the projects received.

Having to narrow down the large pool of high quality proposals to the few that we will be able to fund is challenging. I am pleased to inform you that your proposal was ranked at a sufficiently high position to allow it to be funded. I congratulate you on this success. I would like to note that for Host Institutions based in countries in the process of association to Horizon Europe, the funding is conditional to the relevant association agreement having legal effects either through provisional application or entry into force at the time of signature of the grant agreement.

I am confident that this grant will help you to develop your research at the highest possible level and to achieve ground–breaking results in the spirit of the ERC. We hope that just as the review of your proposal relied on the dedication of external reviewers, so we may rely on your help as remote referee in the future, should your particular expertise be needed.

I wish you all the best in your career and future research.

Yours sincerely,

Professor Maria LEPTIN
President, European Research Council

European Commission

European Research Council Executive Agency
Place Rogier 16, COV2, BE-1049 Brussels, Belgium
E-mail: maria.leptin@ec.europa.eu | Website: erc.europa.eu

PANEL COMMENT

This evaluation report contains the final recommendations and score awarded by the ERC review panel during the second step of the ERC Starting Grant review and the ranking range. The discussion of the panel was conducted within the context of prior reviews submitted by ERC panel members and external referees and the interview with the applicant.

The panel closely examined all the individual review reports and, while not necessarily subscribing to each and every opinion expressed, found that they provide a fair overall assessment. The comments of the individual reviewers are included in this report.

The presentation given by the applicant during the interview and the answers to the questions that were addressed greatly contributed to build the panel's view about the proposal's strengths and weaknesses.

Both the individual reviews and the interview were the basis for the discussion and the final recommendation of the panel.

The panel appreciated the need to improve understanding of the role of fluids in underground deformation and to unravel the degree of fluid control on the different time scales over which deformation processes occur. The proposed laboratory experiments that allow control of the fluid pressure can improve understanding of this problem. The research proposal is comprehensive, comprising fault slip experiments, acoustic imaging, machine learning, and hydromechanical modeling. The work plan is thoughtful and the work packages are reasonably well connected. The project builds on the PI's substantial experience from earlier work and demonstrated technical expertise. The in-situ acoustic monitoring and modeling have the capability of significantly augmenting the value of the laboratory deformation experiments. The panel felt, however, that the proposal provided insufficient detail on individual components. The panel would have liked to see explicit proof of concept for the acoustic imaging and the hydromechanical modeling, and concise statements regarding expected breakthroughs concerning the physical processes involved in deformation under the influence of fluids. The panel was impressed by the interview, in which the PI clearly answered questions, alleviating many of the concerns, although some questions remained as to the feasibility of the laboratory measurements at high frequency and coupling of the different numerical modeling techniques. Overall, the panel recognized the importance of the proposed work and considered the project worthy of support.

The panel therefore recommends the proposal to be retained for funding with a grant not exceeding 1,462,710 Euro.

Final Evaluation

Reviewer N.1	Excellent Very good Very good
Reviewer N.2	Excellent Excellent Excellent
Reviewer N.3	Exceptional Excellent Exceptional
Reviewer N.4	Exceptional Exceptional Exceptional
Reviewer N.5	Exceptional Excellent Exceptional
Reviewer N.6	Exceptional Exceptional Exceptional
Reviewer N.7	Excellent Exceptional Exceptional
Reviewer N.8	Excellent Exceptional Exceptional
Reviewer N.9	Excellent Exceptional Exceptional
Reviewer N.10	Excellent Excellent Excellent

Principal Investigator
To what extent has the PI demonstrated the ability to conduct ground-breaking research?
To what extent does the PI provide evidence of creative independent thinking?
To what extent does the PI have the required scientific expertise and capacity to successfully execute the project?

Comments (Optional for reviewers)
The PI has a strong and integrated background in rock physics, fault rock gouge deformation processes, seismic cycling, experimental geophysics, data processing, and the development of both hardware and software. He has focused his efforts on contributing to the understating of earthquakes. The innovative and creative spirit of the PI is evidenced in his recognition that human-induced seismic events, may provide a rather unique opportunity to formulate a path toward more direct connection between the experimental to natural environments, with the goal of physical understanding of earthquakes, and earthquake prediction. The PI has numerous strong collaborations, awards, and widely cited articles that attest to his ability to recognize and address fundamental challenges in earth science. The PI also has a stated interest in mentoring future generations of scientists; evidence of this passion is embodied in the current proposal design.

Comments (Optional for reviewers)
Dr. Scuderi is a rising "star" in the field of experimental rock physics and laboratory seismology. He not only has an outstanding publication record, with numerous papers in top international journals (e.g. J. Geophys. Res., Nature, Science Advances etc) and substantial number of publications since his Ph.D., but also a very high age-normalized (since PhD) citation index (H = ca. 20; H-normalized ~3). Dr. Scuderi is a creative thinker, gifted experimentalist, but also firm in theory and data analysis. This broad scientific skills set resulted in his prolific publication record. His more recent "expansion" into Machine Learning and numerical modeling, as documented in this proposal, is sort of his "natural response" to be able to address the important scientific questions that he poses. Adding to this portfolio his wide range of collaborators who bring additional expertise and experience into his research efforts, I rate him as an exceptionally capable Principal Investigator from whom we can expect ground-breaking scientific results in the years to come.

ONE YEAR LATER - **ups** and downs

The ERC gives you the unique opportunity to become an independent researcher and a team leader with the potential of carrying state of the art research.

- ~500k euros to spend in new infrastructures
- Build a competitive research team 4 post-doc and 3 PhD
- Foundings for traveling and present at prestigious conferences

ONE YEAR LATER - ups and **downs**

How to manage 1.5M euros in Sapienza

Bureaucracy, bureaucracy and more bureaucracy!!

Keeping track of the **finances** and timesheet you must hire an external accountant paid by you on the overhead.

Purchases: my ERC foreseen to spend

- ~300k euros for a prototype machine
- ~150k euros for a custom made 3D printer

As of today I still could not spend any of those money even if it is **~6 month** that I am trying to make the first purchase. Sapienza keep changing rules and interpretations to Italian laws so that as of today I had start over the procedure 3 times.
However, I become expert in RUP, CUP, DEC codice appalti ANAC … instead of reading papers and do research.

Build a competitive research group

1) the PI cannot choose the collaborators but there is always a competition to carry:
   a) very long time to hire someone (~6month)
   b) unreasonable amount of documentation before and after without a specific office that helps the PI or researcher.

Result: I have lost a few very good researcher

2) Extra-UE researchers are basically impossible to hire. To prepare the documentation for a visa it takes ~6 month plus the competition of other ~6 month.

ONE YEAR LATER - ups and **downs**

How to manage 1.5M euros in Sapienza

Bureaucracy, bureaucracy and more bureaucracy!!

So far I have become an **expert in law** but I still haven’t developed anything related to my project.

Is it the same in other countries or universities?