www.snf.ch
Wildhainweg 3, Postfach 8232, CH-3001 Bern

Application form mySNF

Instrument **Spark**

Part 1: General Information

Basic data

Project Title	Deep generative modelling for gravitational lensing fields from 3D models of galaxies
Project title in English	Deep generative modelling for gravitational lensing fields from 3D models of galaxies

Research Field	Mathematics, natural sciences
Main Discipline	20200 Astronomy, Astrophysics and Space Sciences
University	Zürcher Hochschule f. Angew. Wissenschaften - ZHAW

Applicant(s)

Main Applicant	**Philipp Denzel**

Grant Application

Amount requested (CHF)	Total	**96'968**
Requested starting date	**01.11.2023**	
Duration (6-12 months)	**12**	

Attachments

Project description	gl3dgen_spark_23.pdf
CV	CV_Denzel_i01gz647k49tvcwzfy4xsvhpk3q8.pdf
Employment confirmation	confirmation_of_employment_letter_Denzel_signed.pdf

1. Responsible applicant

Last name	**Denzel**
First name	**Philipp**
Function (title)	
Academic degree	Dr./PhD
Date of birth	19.08.1991
Gender	männlich
Swiss social security number	756.7165.9375.87
Language	Deutsch
Nationality	Deutschland
Correspondence address of application	Address of workplace

Home address

Address supplement	
Street, No.	Breitwiesstrasse 61
P.O. Box	
Postcode / Zipcode	8135
Place	Langnau am Albis
Country	Schweiz

Current work address (if available)

Designation 1 (lab/research group)*	Center for Artificial Intelligence
Designation 2 (inst /dept.)*	School of Engineering
Designation 3 (University)*	ZHAW
Street, No.	Technikumstrasse 71
Address supplement 1 (e.g. building)	TN
Host (Head of the institute/ department, Grants Office) *	Prof. Dr. Thilo Stadelmann
P.O. Box	
Postcode / Zipcode	8400
Place	Winterthur
State, canton, etc.	ZH
Country	Schweiz

Communication

Secretariat line	
Switchboard	
Direct line	
Fax office	
Home telephone number	
Cellphone	+41 76 211 19 08
Website	
E-mail address	phdenzel@gmail.com

2. Host research group

General information

Designation 1 (lab/research group)*	**Centre for Artificial Intelligence**
Designation 2 (inst /dept.)*	**School of Engineering**
Designation 3 (University)*	**ZHAW**
Address supplement 1 (e.g. building)	TN
Host (Head of the institute/ department, Grants Office) *	Prof. Dr. Thilo Stadelmann
Street, No.	Technikumstrasse, 71
P.O. Box	
Postcode / Zipcode	8400
Place	Winterthur
State, canton, etc.	ZH
Country	Switzerland
Planned start of the project	01.11.2023
Planned end of the project	02.08.2024

Communication

Secretariat line	+41 58 934 72 08
Switchboard	
Website	www.zhaw.ch/cai
E-mail address	thilo.stadelmann@zhaw.ch

3. Applicant's employment

Information on employment and function at the anticipated starting date of the grant

Name	**Denzel, Philipp**
Employment at the anticipated starting date of the grant	befristet bis...
fixed-term contract until	30.06.2025
Level of employment %	100
Function in the context of this grant application	Postdoktorand/in, Research associate, Assistenzärztin/Assistenzarzt
Professorship	Keine
Doctorate (PhD)?	Yes
Date of doctorate (PhD)	29.10.2020
PhD supervisor	Prof. Dr. Prasenjit Saha
Country of doctorate	Schweiz
Remarks	
Further employments	

4. Basic data I

Title in English	Deep generative modelling for gravitational lensing fields from 3D models of galaxies
Original title (if different)	
Requested starting date	01.11.2023
Duration (6-12 months)	12
Research field	Mathematics, natural sciences
Further research fields	Engineering sciences
Main discipline	20200 Astronomy, Astrophysics and Space Sciences
Sub-discipline(s)	20506 Information Technology

5. Basic data II

Summary (copy of the summary in the project description)

This is a research proposal for the development of a novel technique using generative deep learning for modelling galaxies of gravitational lens systems in 3D, opposed to conventional methods limited to 2D.
Gravitational lensing is a phenomenon that occurs when rays of light from a distant background source are deflected by the gravitational field of a massive foreground object, e.g. a galaxy, which almost perfectly aligns with the observer. While such occurrences are rare, they are scientifically significant, because they provide the only opportunity to directly infer the lensing galaxy's mass distribution, including its dark matter content. This unique perspective on a galaxy's dark matter distribution offers exceptional insights into the mysteries surrounding galaxy evolution, the nature of dark matter,
galaxy substructures, and even the expansion of the Universe.
Accurately predicting the deflection field of a strong gravitational lens is a complex task that requires a detailed understanding of the distribution of matter in the lensing galaxy. Conventional methods for calculating these deflection fields, such as ray-tracing, are computationally expensive, can take a long time to generate results, and typically have to be fine-tuned by an experienced expert.

In recent years, deep learning methods have emerged as a promising approach for generating and processing image-based data in various scientific fields, often with super-human proficiency. These methods employ neural networks to learn the mapping between the input properties (for instance, the lensing galaxy) and the resulting image (in this instance, the deflection field).

In this research proposal, I outline the usage of generative deep learning methods to produce strongly lensing deflection fields of 3D galaxy models from existing hydrodynamical simulation suites for the purpose of creating mock observations, observational fits, and corresponding source reconstructions. Specifically, we will explore various state-of-the-art deep learning architectures, including diffusion models, vision transformers, generative adversarial networks (GANs), and variational autoencoders (VAEs) to develop a model that can accurately generate the deflection field from a given 3D galaxy
model. The resulting deep learning model will be used to create synthetic observations that can be compared to existing observational data to test the accuracy of the lens model, and in particular investigate the theoretical properties of the observed lensing galaxies and their corresponding background source reconstructions, within a Bayesian framework.

Lens modelling is inherently considered as a (degenerate) 2D inverse problem. The novelty of this project consists of introducing 3D models as direct input, which requires methods able to cover a broad range in solution space due to the degeneracy introduced thereby. Conventional modelling methods are insufficient due to the typically low complexity of their models whereas deep learning methods increase the model complexity with a high number of parameters, thus able to span a wider range in solution space.

As of today, roughly 10^3 lenses have been discovered, only a fraction of those properly analysed. Moreover, it is anticipated that the next-generation satellites and telescopes such as JWST, Euclid, SKA, or ELT may increase this number to 10^5. Thus, it is crucial to devise novel techniques that can scale with big data efficiently.

Keywords	Gravitational lensing
	Artificial Intelligence
	Deep Learning
	Galaxy formation
	Hydrodynamical simulations
	Astronomical data
Language of correspondence	German
Financial administration	ZHAW Zürcher Hochschule für Angewandte Wissenschaften

6. Host institution

University	Zürcher Hochschule f. Angew. Wissenschaften - ZHAW
Remarks	

7. Requested funding

Requested funding	**Total (CHF)**	**Year 1**
Total (CHF)	**96'968**	**96'968**

Salaries	**Total (CHF)**	**Year 1**
The applicants' own salaries	12'165	12'165
Salary for further employees	71'429	71'429
Total (CHF)	**83'594**	**83'594**
Total (%)	**86%**	**86%**

Social security contributions	**Total (CHF)**	**Year 1**
Social security contributions	13'374	13'374
Total (CHF)	**13'374**	**13'374**
Total (%)	**14%**	**14%**

Details

The applicants' own salaries		**Total (CHF)**	**Year 1**
Denzel, Philipp: n.n.		12'165	12'165
Work-time percentage	Year 1: 10.00%		
Social security contributions	Year 1: 16.00%		
Total (CHF)		**12'165**	**12'165**
Total (%)		**13%**	**13%**

Salary for further employees		**Total (CHF)**	**Year 1**
Advisor/AI Development: Frank-Peter Schilling		9'732	9'732
Work-time percentage	Year 1: 4.00%		
Social security contributions	Year 1: 16.00%		
Comments / Additions	Frank-Peter Schilling has expertise in AI, specifically 3D deep learning approaches, and will help with the implementation of the AI components of this project.		
Person	Frank-Peter Schilling male / 06.08.1970 German / Germany		
Academic degree	Prof.		

AI/software development: n.n.		52'138	52'138
Work-time percentage	Year 1: 65.00%		
Social security contributions	Year 1: 16.00%		
Comments / Additions	This person will have expertise in AI and (scientific) software development. She or he will mainly be in charge of code implementations, and run tests of the different deep learning methods.		
Co-PI: Elena Gavagnin		9'559	9'559
Work-time percentage	Year 1: 5.00%		
Social security contributions	Year 1: 16.00%		
Comments / Additions	Elena Gavagnin agreed to act as Co-PI for this project. She has expertise in both astrophysics and artificial intelligence. She will help with any administrative work, contribute to the AI development, normally act in an advisory role, and as my replacement in the out of ordinary case.		
Person	Elena Gavagnin female / 19.07.1988 Number of children 1 / English / Italy		
Academic degree	Dr./PhD		
Total (CHF)		**71'429**	**71'429**
Total (%)		**74%**	**74%**

Social security contributions	**Total (CHF)**	**Year 1**
Advisor/AI Development: Frank-Peter Schilling	1'557	1'557
AI/software development: n.n.	8'342	8'342
Co-PI: Elena Gavagnin	1'529	1'529
Denzel, Philipp	1'946	1'946
Total (CHF)	**13'374**	**13'374**
Total (%)	**14%**	**14%**

8. Collaboration (national and international)

Person/Institution	Prof. Dr. Prasenjit Saha/University of Zurich
Country	Switzerland
Context	Prof. Saha agreed to provide his expertise in the field of gravitational lensing. He will take an adivsory role and help in writing the scientific publications.
Types of collaboration	in-depth/constructive exchanges on approaches, methods or results
	Publication

Person/Institution	Dr. Elena Gavagnin/ZHAW
Country	Switzerland
Context	Dr. Gavagnin agreed to assist in almost any aspects of the project (and will act as Co-PI). She can share her expertise in astrophysical hydrodynamical simulations and artifical intelligence, refer research assistants, host meetings if necessary, and will help in writing the scientific publications.
Types of collaboration	in-depth/constructive exchanges on approaches, methods or results
	Publication
	Research Infrastructures
	Exchange of personnel

Person/Institution	Prof. Dr. Frank-Peter Schilling/ZHAW
Country	Switzerland
Context	Prof. Dr. Schilling agreed to assist in almost any aspects of the project. He can share his expertise in artifical intelligence and deep learning, refer research assistants, and will help in writing the scientific publications.
Types of collaboration	in-depth/constructive exchanges on approaches, methods or results
	Publication
	Research Infrastructures

Exchange of personnel

9. Research requiring authorisation or notification

HRA-relevant and HRA-irrelevant research involving humans	No
Research on human embryonic stem cells	No
Research on animals	No
Research on GMO or pathogens	No

10. 3R – Replace, Reduce, Refine

Project does not involve any animal experiments	Yes
Project involves experiments with animals that fall under the Animal Welfare Act (vertebrates, cephalopods, crayfish) and takes account of the 3R	No
Project is a 3R research project focusing on "Replace"	No
Project is a 3R research project focusing on "Reduce"	No
Project is a 3R research project focusing on "Refine"	No
Project involves experiments with animals that do not fall under the Animal Welfare Act (insects, worms)	No

11. Access and Benefit Sharing (ABS)

The research project plans to use genetic resources that are governed by the ABS provisions of the Nagoya Protocol	No

12. Fellowships for a research stay abroad

Project involves experiments that require authorisation and notification. I hereby confirm compliance with Swiss laws and ethical guidelines.	No

13. Awareness of the relevant regulations

Relevant regulations noted and accepted	Yes