# Tomasz Kacprzak

Senior Scientist, Cosmology Group, ETH Zurich
Senior Data Scientist, Swiss Data Science Center

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## Employment

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|---|---|
| 2018 - present | **Senior Scientist**, Institute for Particle Physics and Astrophysics, ETH Zurich<br>Idea originator and lead advisor for 7 PhD student papers and 8 MSc papers<br>First author of 2 papers, including in Physical Review X, public dataset CosmoGridV1 |
| 2021 - present | **Senior Data Scientist**, Swiss Data Science Center<br>Collaborations for adaptation of data science in physics and climate science |
| 2014 - 2018 | Post-doctoral research associate, Institute for Astronomy, ETH Zurich<br>First author of 3 papers, advisor: Prof Alexandre Refregier |

## Education

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|---|---|
| 2010 - 2014 | **PhD in Physics and Astronomy**, University College London, UK<br>Advisors: Prof Sarah Bridle, Prof John Shawe - Taylor<br>Thesis topic: *Statistical problems in Weak Gravitational Lensing* |
| 2009 - 2010 | **MSc Machine Learning**, First Class, University College London, UK<br>Advisors: Prof John Shawe-Taylor, Prof Ofer Lahav<br>Thesis topic: *Kernel methods for galaxy morphological classification* |

## Awards

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|---|---|
| 2024 - 2025 | NERSC Generative AI for Science Project: *DES+DESC Generative AI for Cosmology*<br>**Principal Investigator**, 7'000 A100 GPU Node Hours, ≈40k USD<br>Awarded by the National Energy Research Scientific Computing Center, USA |
| 2023 - 2025 | NERSC Exascale Science Applications Program, Project: *DESLearning*<br>**Principal Investigator**, 0.5 NERSC FTE algorithmic and technical support |
| 2020 - 2021 | Computational production project: *Measuring Dark Energy with Deep Learning*<br>**Principal Investigator**, value 750'000 GPU-node hours, ≈500 kCHF<br>Awarded by the Swiss National Supercomputing Center, www.cosmogrid.ai |
| 2017 - 2019 | Grant: *Deep Learning for Observational Cosmology*<br>**Principal Investigator**, hired staff: N. Perraudin (postdoc), J. Fluri (PhD)<br>Awarded by Swiss Data Science Center, ≈500k CHF |
| 2019 | Workshop: *Artificial Intelligence Methods in Cosmology*, June 9-12<br>Main applicant and lead organizer, ≈5k CHF<br>Awarded by ETHZ Congressi Stefano Franscini |

## Major scientific achievements

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|---|---|
| 2018 - present | Introduction of deep learning to cosmology, from prototypes [1807.08732], first practical measurements [1906.03156], and mature measurements [2201.07771]. |
| 2015 - present | Leadership of the simulation-based inference in Dark Energy Survey, using shear peak statistics for the SV [1603.05040] and Year 3 [2110.10135] cosmology constraints. |
| 2016 - present | Lead of an independent, full image-level reanalysis of the Dark Energy Survey Year 1 data using simulation-based forward modelling framework MCCL [1906.01018]. |

## Application history

Shortlisted for the position of *Lecturer in AI and Data Science in Astronomy*, University of Southampton (2024), submitted ERC Starting Grant (2021, CSIC Barcelona), result in top 17% percentile.

## Leadership and service

**2024 - present**   **Member of the Euclid collaboration**
- Design of SBI simulations for Cosmological Simulations Working Group
- Internal reviewer for papers in the area of SBI and higher-order statistics

**2023 - present**   **Member of the SKA Switzerland Consortium**
- Coordinated SNF NCCR *D+Cosmos* grant submission for Swiss SKA and LISA science, pillar *Digital Frontier* (Data Science and AI), 14 PIs, budget ≈12m CHF
- Developing multiprobe SBI projects for combining SKA and LSST/Euclid

**2022 - present**   **Simulations Working Group Coordinator in the Dark Energy Survey**
- Leading a group of 30 DES members, 10 cosmology projects with SBI
- Providing simulated theory prediction for multiprobe SBI projects
- Coordinating submissions for competitive computing resources grants
- Organizing bi-montly calls for project updates, planning and invited talks

**2022 - present**   **Member of the Science Committee in the Dark Energy Survey**
- Coordinating design of new innovation-oriented projects
- Designing publication policy

**2022 - present**   **Builder of the Dark Energy Survey**
- Permanent *Builder* status awarded after 2 FTE of DES infrastructure work
- In-person participation in 15 DES collaboration meetings
- Co-wrote Im3shape, a weak lensing measurement code for DES SV and Y1
- Performed simulations-based shear calibration in DES SV
- Leader of the *Early Career Scientist Committee* 2016-2017, representing junior researchers with survey management, organizing educational and career events

**2021 - present**   **Proposal Reviewer** Swiss Data Science Center calls for collaborative projects
- Reviewed ∼ 20 interdisciplinary proposals for data science and STEM domains
- Helped applicants to strenghten their proposals through individual consulting

**2018 - present**   **Service in astrophysics and computer science**
- Science Organizing Committee Member *UniverseAI*, Athens 2-6 June 2025
- Reviewer for the *Application Track* at *Supercomputing 2024*, Atlanta, Nov 17-22
- Paper reviewer for Nature Astronomy, PNAS, Physical Review, JCAP, MNRAS

**2018 - 2019**   **Lead organizer of workshop** *Artificial Intelligence Methods in Cosmology*
- Monte Verita, Ascona, June 2019, 46 participants, 6 invited speakers
- Lead grant writer, speaker invitations, progam development, logistics

## Teaching

**2019 - 2020**   Lecturer for UG course *Statistical Methods and Analysis in Experimental Physics*
Topical block: Bayesian methods, machine learning, simulations-based inference
Tasks: lectures, preparing assignments, leading the tutorials for approx. 50 students

**2019**   Lecturer for the UG course *Astrophysics 1*, topical block: *Introduction to Cosmology*

**2019 - 2020**   Guest lecturer for UG course *Introduction to Data Science* at University of Zurich
Topics: deep learning, convolutional neural networks, generative models

**2017 - 2018**   Course coordinator for undergraduate module *Physics 1 and 2*, approx. 300 students
Tasks: creation of exercises, preparation of exams and coordination of marking

**2016 - 2017**   Teaching assistant for MSc course *Advanced Statistical Methods in Cosmology*
Tasks: curriculum development, creating assignments, leading tutorials

**2017**   Leader of the tutorial sessions, masters-level module *Cosmological Probes*

## Supervision

I proactively seek opportunities to supervision graduate students, propose projects topics, and advise students throughout their theses. I was the **idea originator and lead advisor for 3 post-doc projects, 7 PhD projects, 13 MSc projects.** 8/13 MSc projects resulted in articles published in peer-reviewed journals, marked with ☑.

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|---|---|---|
| 2024 - present | Jozef Bucko, post-doc, | *Peak statistics of combined probes in DES* |
| 2022 - present | Arne Thomsen, PhD, | *Cosmology with deep learning of combined probes in DES* |
| 2021 - present | Beatrice Moser, PhD, | *Evolution of galaxy samples with ABC forward modelling in DES* |
| 2023 - present | Silvan Fischbacher, MSc, | *SBI for galaxy polulation evolution modelling* |
| 2023 | Virginia Ajani, post-doc, | *Peak statistics of combined probes in DES* |
| 2022 | Silvan Fischbacher, MSc, | *Redshift requirements for shear with intrinsic alignment* ☑ |
| 2022 | Gaspard Aymerich, MSc, | *Interpretability of deep-learning methods applied to LSS surveys* |
| 2022 | Ting Tan, MSc, | *Assessing theoretical uncertainties for cosmological from weak lensing* ☑ |
| 2022 | Dominik Zürcher, PhD, | *Dark energy survey year 3 results: Cosmology with peaks* ☑ |
| 2022 | Janis Fluri, PhD, | *Full wCDM Analysis of KiDS-1000 Lensing Using Deep Learning* ☑ |
| 2018 | Nathanael Perraudin, post-doc data scientist, | *Deep learning on the sphere* ☑ |
| 2020 | Timothy Wing Hei Yiu, MSc, | *A tomographic mass map emulator of KiDS-1000* ☑ |
| 2020 | Benjamin Suter, MSc, | *Cosmology with machine learning and humand -designed statistics* |
| 2019 | Dominik Zürcher, PhD, | *Forecast for non-Gaussian statistics in large-scale surveys* ☑ |
| 2019 | Janis Fluri, PhD, | *Constraints with deep learning from KiDS-450 weak lensing maps* ☑ |
| 2019 | Conrad Schwanitz, MSc, | *Interpretability measures for deep learning on lensing maps* |
| 2019 | Sajanth Subramaniam, MSc, | *Systematics-invariant constraints with deep learning* ☑ |
| 2018 | Jörg Herbel, PhD, | *Fast Point Spread Function Modeling with Deep Learning* ☑ |
| 2018 | Sandro Marcon, MSc, | *Emulation of cosmological mass maps with conditional GANs* ☑ |
| 2018 | Ankit Srivastava, MSc, | *Cosmological N-body simulations: a challenge for scalable GANs* ☑ |
| 2018 | Janis Fluri, PhD, | *Constraints from noisy convergence maps through deep learning* ☑ |
| 2018 | Alex Stauffer, MSc, | *Approximate Bayesian Computation in cosmology with ABCpy* |
| 2018 | Jonathan Rosenthal, MSc, | *Generative Temporal Models for Cosmology* |
| 2017 | Janis Fluri, MSc, | *Lensing peak statistics in the era of large scale cosmological surveys* ☑ |
| 2017 | Andres Rodrigues, MSc, | *Fast cosmic web with generative adversarial networks* ☑ |
| 2017 | Jorit Schmelzle, MSc, | *Cosmological model discrimination with deep learning* |

## Recent presentations

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| 2023/11 | *Debating the Potential of ML in Astro. Surveys*, IAP Paris, FR, | **invited review talk** |
| 2023/11 | *Mathematics and Informatics Colloquium*, Uni Basel, CH, | <u>invited seminar</u> |
| 2023/06 | *Emerging topics in applications of Optimal Transport*, ITS, ETH Zurich, CH | |
| 2023/05 | *ML X Astrophysics Symposium*, Flatiron Institute, New York, USA, | <u>invited talk</u> |
| 2023/03 | *University Observatory Munich Colloquium*, DE, | <u>invited talk + 2-day tutorials</u> |
| 2022/07 | *Key Challenges in Galaxy and CMB lensing*, Cambridge, UK, | <u>invited guest talk</u> |
| 2022/06 | *Bayesian Deep Learning in Cosmology*, Paris, FR, | **invited keynote talk** ☑ |
| 2022/06 | *Space Science Data Center Seminar*, Rome, IT, | <u>invited seminar talk</u> |
| 2022/04 | *Berkeley ML and Science Forum*, Berkeley, USA, | <u>invited seminar talk</u> |
| 2021/10 | *Cosmology seminar*, University of Geneva, CH, | <u>invited seminar talk</u> |
| 2021/05 | *Dark Energy Spectroscopic Instrument: Artificial Intelligence Seminar*, | <u>invited talk</u> |
| 2019/12 | *Machine Learning Tools for Research in Astronomy Workshop*, Ringberg, DE | |
| 2019/09 | *Cosmology seminar*, SLAC, Stanford, USA, | <u>invited talk</u> |

# Publications

Authored 24 papers on own original ideas, including 8 as the lead author. Significantly contributed to 13 papers by students in a support role, and 33 international collaboration papers.

Selected papers on own original ideas, lead author or lead advisor:

**CosmoGridV1: a simulated $w$CDM theory prediction for map-level cosmological inference**
T. Kacprzak, J. Fluri, A. Schneider, A Refregier, J Stadel
JCAP 2023, 02, 050, 29, 2209.04662

**DeepLSS: breaking parameter degeneracies in large scale structure with deep learning of combined probes**
T. Kacprzak, J. Fluri
**PhysRevX (impact factor 14.5)**, 2022, 2, 031029, 2203.09616

**A Full wCDM Analysis of KiDS-1000 Weak Lensing Maps using Deep Learning**
J. Fluri, T. Kacprzak, A. Lucchi, A. Schneider, A. Refregier, T. Hofmann
PhysRevD, 2022, 105, 8, 083518, 2201.07771

**Cosmological constraints with deep learning from KiDS-450 weak lensing maps**
J. Fluri, T. Kacprzak, A. Lucchi, A. Refregier, A. Amara, T. Hofmann, A. Schneider
PhysRevD, 2019, 100, 6, 1906.03156

**DeepSphere: Efficient spherical convolutional neural network with HEALPix sampling for cosmology**
N. Perraudin, M. Defferrard, T. Kacprzak, R. Sgier
Astronomy and Computing, 2019, 27, 130, 1810.12186

**Cosmological constraints from noisy convergence maps through deep learning**
J. Fluri, T. Kacprzak, A. Lucchi, A. Refregier, A. Amara, T. Hofmann
PhysRevD, 2018, Vol. 98, 12, 1807.08732

**Emulation of cosmological mass maps with conditional generative adversarial networks**
N. Perraudin, S. Marcon, A. Lucchi, T. Kacprzak
Front. Artif. Intell., 04, 06, 2021, 2004.08139

**Fast Cosmic Web Simulations with Generative Adversarial Networks**
A. C. Rodriguez, T. Kacprzak, A. Lucchi, A. Amara, R. Sgier, +3 authors
CompAst, 2018, 5, 1, 4, 11, 1801.09070

**Cosmology constraints from shear peak statistics in Dark Energy Survey Science Verification data**
T. Kacprzak, D. Kirk, O. Friedrich, + 84 authors (DES collaboration)
MNRAS, 2016, 463, 4, 1603.05040

**Dark Energy Survey Year 3 results: Cosmology with peaks using an emulator approach**
D. Zürcher, ... T. Kacprzak, + DES Collaboration (102 authors)
MNRAS, 2022, 511, 2, 2075-2104, 2110.10135

**A tomographic spherical mass map emulator of the KiDS-1000 survey using conditional GANs**
T. W. H. Yiu, J. Fluri, T. Kacprzak
JCAP 2022, 12, 013, 40, 2112.12741

**Measurement and calibration of noise bias in weak lensing galaxy shape estimation**
T. Kacprzak, J. Zuntz, B. Rowe, S. Bridle, A. Refregier, A. Amara, L. Voigt, M. Hirsch
MNRAS, 2012, 427, 1203.5049

**Monte Carlo Control Loops for cosmic shear cosmology with DES Year 1**
T. Kacprzak, J. Herbel, A. Nicola, + 53 authors (DES collaboration)
PhysRevD, 2020, 101, 8, 082003, 1906.01018

**Fast Point Spread Function Modeling with Deep Learning**
J. Herbel, T. Kacprzak, A. Amara, A. Refregier, A. Lucchi
JCAP, 2018, 07, 54, 1801.07615

**Redshift requirements for cosmic shear with intrinsic alignment**
S. Fischbacher, T. Kacprzak, J. Blazek, A. Refregier
JCAP 2023, 01, 033, 37, 2207.01627

**Simulation-based inference of deep fields: galaxy population model and redshift distributions**
B. Moser, T. Kacprzak, S. Fischbacher, A. Refregier, D. Grimm, L. Tortorelli
JCAP 2024, 05, 049, 37, 2401.06846

**Cosmology from Galaxy Redshift Surveys with PointNet**
S. Anagnostidis, A. Thomsen, T. Kacprzak, T. Tröster, L. Biggio, A. Refregier, T. Hofmann
Machine Learning and the Physical Sciences, NeurIPS 2023, 2401.06846

Selected papers with substantial contribution:

**Dark Energy Survey Year 3 Results: Cosmology from Cosmic Shear and Robustness to Modeling**
L. Secco, ..., T. Kacprzak, + The DES Collaboration (153 authors)
PhysRevD, 2022, 105, 2, 023515, 2105.13544
Role: DES internal reviewer for this paper

**Dark Energy Survey Year 1 results: Cosmological constraints from cosmic shear**
M.A. Troxel, ..., T. Kacprzak, + 134 authors (DES collaboration)
PhysRevD, 2018, 98, 4, 043528, 1708.01538
Role: wrote IM3SHAPE, calibration and testing of shear catalog

**Dark Energy Survey year 1 results: Cosmological constraints from galaxy clustering and weak lensing**
T.M.C. Abbott, ..., T. Kacprzak, + 199 authors (DES collaboration)
PhysRevD, 2018, 98, 4, 043526, 1708.01530
Role: wrote IM3SHAPE, calibration and testing of shear catalog

**Cosmology from cosmic shear with Dark Energy Survey Science Verification data**
The Dark Energy Survey Collaboration (128 authors, alphabetical) + T. Kacprzak
PhysRevD, 2016, 94, 2, 1507.05552
Role: measurement and calibration of the cosmic shear signal, creation of simulations for testing and calibration

**The DES Science Verification weak lensing shear catalogues**
M. Jarvis, E. Sheldon, J. Zuntz, T. Kacprzak, S. L. Bridle + 90 authors (DES collaboration)
MNRAS, 2016, 460, 2, 1507.05603
Role: creation of simulations to test the methods, calibrations for the Im3shape measurement, paper writing

**Cosmic shear measurements with Dark Energy Survey Science Verification data**
M.R. Becker, ..., T. Kacprzak, + 104 authors (DES collaboration)
PhysRevD, 2016, 94, 2, 022002, 1507.05598
Role: wrote IM3SHAPE, calibration and testing of shear catalog

**Cosmological Parameter Estimation and Inference using Deep Summaries**
J. Fluri, A. Lucchi, T. Kacprzak, A. Refregier, T. Hofmann
PhysRevD, 2021, 104, 12, 123526, 2107.09002
Role: coordinating the collaboration with computer scientists Aurelien Lucchi and Thomas Hofmann, comments

**Rapid Simulations of Halo and Subhalo Clustering**
P. Berner, A. Refregier, R. Sgier, T. Kacprzak, L. Tortorelli, P. Monaco
JCAP 2022, 11, 002, 29, 2112.08389
Role: consulting, comments

**The PAU Survey: Measurement of galaxy properties with Approximate Bayesian Computation**
L. Tortorelli, M. Siudek, B. Moser, T. Kacprzak, ... + 21 authors (The PAUS Collaboration)
JCAP, 2021, 12, 013, 45, 2106.02651
Role: developing the galaxy population model and the Approximate Bayesian Computation engine

**The redshift distribution of cosmological samples: a forward modeling approach**
J. Herbel, T. Kacprzak, A. Amara, A. Refregier, C. Bruderer, A. Nicola
JCAP, 2017, 08, 035, 1603.05040
Role: contribution to model building and algorithms, co-advisor of J. Herbel (PhD student)

**Fast Forward Modelling of Galaxy Spatial and Statistical Distributions**
P. Berner, A. Refregier, B. Moser, L. Tortorelli, L. F. Machado Poletti Valle, T. Kacprzak
JCAP, 2024, 04, 023, 33 2310.15223
Role: consulting, comments

**Towards a full wCDM map-based analysis for weak lensing surveys**
D. Zürcher, J. Fluri, V. Ajani, S. Fischbacher, A. Refregier, T. Kacprzak
MNRAS, 2023, 525, 1, 2206.01450
Role: providing simulated theory prediction, consulting, comments, co-advisor of D. Zürcher

**GREAT3 results - I. Systematic errors in shear estimation and the impact of real galaxy morphology**
R. Mandelbaum, ..., T. Kacprzak, ... (43 authors)
MNRAS, 2015, 450, 3, 2963-3007, 1412.1825
Role: submission to the GREAT3 competition with the IM3SHAPE results

**GALSIM: The modular galaxy image simulation toolkit**
B.T.P. Rowe, ..., T. Kacprzak, ... (15 authors)
Astronomy and Computing, 2015, 10, 121-150, 1407.7676
Role: development of GALSIM, extended testing of the convolution module

**Noise bias in weak lensing shape measurements**
A. Refregier, T. Kacprzak, A. Amara, S. Bridle, B. Rowe
MNRAS, 2012, 425, 1951, 1203.5050
Role: idea development, paper writing