

# Job Leon Feldbrugge

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## Referees

**Prof. Neil Turok**, University of Edinburgh, Edinburgh, Scotland and Perimeter Institute for Theoretical Physics, Waterloo, Canada ([neil.turok@ed.ac.uk](mailto:neil.turok@ed.ac.uk))

**Prof. Ue-Li Pen**, Academia Sinica, Taipei, Taiwan and Canadian Institute for Theoretical Astrophysics, Toronto, Canada ([pen@cita.utoronto.ca](mailto:pen@cita.utoronto.ca))

**Prof. Rien van de Weygaert**, University of Groningen, Groningen, The Netherlands ([weygaert@astro.rug.nl](mailto:weygaert@astro.rug.nl))

## Academic positions

2021 - present

**HIGGS FELLOW** at the Higgs Centre for Theoretical Physics at the University of Edinburgh (Scotland)

2019 - 2021

**POSTDOC** at the Perimeter Institute (Canada) and the Department of Physics, Carnegie Mellon University (United States)

## Education

2015 - 2019

**PHD** Physics, Perimeter Institute, University of Waterloo

*Advisor:* Neil Turok

*Thesis:* Path integrals in the sky: Classical and quantum problems with minimal assumptions

*Defence date:* October 17, 2019

2014 - 2015

**MASTER** Part III Mathematics (*with distinction*), University of Cambridge

*Committee:* Paul Shellard and Tommaso Giannantonio

*Thesis:* Primordial non-Gaussianity and large-scale structure

2012 - 2014

**MASTER** Physics (*cum laude*), van Swinderen Institute, University of Groningen

2012 - 2014

**MASTER** Astronomy (*cum laude*), Kapteyn Institute, University of Groningen

2012 - 2014

**MASTER** Mathematics (*cum laude*), Bernoulli Institute, University of Groningen

*Committee:* Rien van de Weygaert (cosmology and large-scale structure formation)

Diederik Roest (string cosmology)

Aernout van Enter (statistical mechanics)

*Thesis:* Statistics of caustics in large-scale structure formation

2009 - 2012

**BACHELOR** Physics (*cum laude*), van Swinderen Institute, University of Groningen

2009 - 2012

**BACHELOR** Astronomy (*cum laude*), Kapteyn Institute, University of Groningen

2009 - 2012

**BACHELOR** Mathematics (*cum laude*), Bernoulli Institute, University of Groningen

*Committee:* Rien van de Weygaert (cosmology and large-scale structure formation)

Elisabetta Pallante (quantum field theory)

Gert Vegter (computational geometry)

*Thesis:* Analysis of Betti numbers and persistence diagrams of 2D Gaussian random fields

July 2016

**SUMMER SCHOOL** It from qubit summer school, Perimeter Institute, Canada (two weeks)

July 2015

**SUMMER SCHOOL** Prospects in theoretical physics: new insights into quantum matter, Institute for Advanced Studies, Princeton (one week)

July 2015

**SUMMER SCHOOL** Princeton summer school on condensed matter physics (one week)

August 2011

**SUMMER SCHOOL** Dealing with environmental heritage, Bath, United Kingdom (two weeks)

July 2010

**SUMMER SCHOOL** University of Cambridge international summer school in science (two weeks)

## Awards

April 2020	Canadian Association of Physicists' Division of Theoretical Physics (DTP) and Winnipeg Institute for Theoretical Physics (WITP) P.R. Wallace PhD Thesis Prize Best PhD thesis in Theoretical Physics from a Canadian university (2020).
November 2014	De Zeeuw-Van Dishoeck award 2014 Best master thesis in Astronomy from a Dutch university (2014).
July 2014	GUF-100 prize 2014 Best student in the Faculty of Mathematics and Natural Sciences at the University of Groningen (2014).
November 2011	Silver medal in the university physics competition 2011 A university competition in which groups of three physics students all over the world solve a problem and write an article in 48 hours.
September 2010	Young Talent encouragement prize 2010 in Physics Prize awarded by the Koninklijke Hollandse Maatschappij der Wetenschappen (Royal Holland Society of Sciences and Humanities) for the best freshman Physics student at the University of Groningen in 2009-2010.
November 2007	Third place in the CanSat competition The CanSat project is an annual competition organized by the Delft University of Technology. Teams of secondary school students design and build a satellite in a Coca-Cola can.

## Scholarships

March 2015	University of Waterloo scholarship, for PhD at the Perimeter Institute
July 2014	Hendrik Muller fund 2014: Scholarship for excelling Dutch students
June 2014	VSB fund 2014: Scholarship for Dutch students studying in abroad

## Research Visits

May 2023	Research visit to Beatrice Bonga, Radboud University, Nijmegen, The Netherlands
March 2023	Research visit to Ue-Li Pen, Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan
March 2023	Research visit to Beatrice Bonga, Radboud University, Nijmegen, The Netherlands
January 2023	Research visit to Beatrice Bonga, Radboud University, Nijmegen, The Netherlands
June 2022	Research visit to Rien van de Weygaert, Kapteyn Institute, Groningen, The Netherlands
January 2020	Research visit to Beatrice Bonga, Radboud University, Nijmegen, The Netherlands
June 2019	Research visit to Rien van de Weygaert, Kapteyn Institute, Groningen, The Netherlands
October 2018	Research visit to Rien van de Weygaert, Kapteyn Institute, Groningen, The Netherlands
May 2018	Research visit to Jean-Luc Lehnars, Albert Einstein Institute, Potsdam, Germany
Feb - Apr 2017	Research visit to DAMTP, University of Cambridge, United Kingdom
March 2017	Research visit to Jean-Luc Lehnars, Albert Einstein Institute, Potsdam, Germany

## Publications & talks

### JOURNAL ARTICLES

2023	<b>J. Feldbrugge</b> , "Complex evaluation of angular power spectra: Going beyond the Limber approximation", <i>Physical Review D</i> (2023, R&R). <a href="#">arXiv:2304.13064</a> [ <a href="#">astro-ph.CO</a> ]
2023	<b>J. Feldbrugge</b> , Y. Yan, and R. van de Weygaert, "Statistics of tidal and deformation eigenvalue fields in the primordial Gaussian matter distribution: the two-dimensional case", <i>Monthly Notices of the Royal Astronomical Society</i> (2023, R&R). <a href="#">arXiv:2301.07200</a> [ <a href="#">astro-ph.CO</a> ]
2023	<b>J. Feldbrugge</b> , and R. van de Weygaert, "Cosmic web & caustic skeleton: non-linear constrained realizations - 2D case studies", <i>Journal of Cosmology and Astroparticle Physics</i> (2013) no.2, 58. <a href="#">arXiv:2212.07840</a> [ <a href="#">astro-ph.CO</a> ]
2023	<b>J. Feldbrugge</b> , U.-L. Pen, and N. Turok, "Oscillatory path integrals for radio astronomy," <i>Annals of Physics</i> (2023) no.451, 169255. <a href="#">arXiv:1909.04632</a> [ <a href="#">astro-ph.HE</a> ]
2023	<b>J. Feldbrugge</b> , "Multi-plane lensing in wave optics," <i>Monthly Notices of the Royal Astronomical Society</i> (2023) nr.250, 2995-3006. <a href="#">arXiv:2010.03089</a> [ <a href="#">astro-ph.CO</a> ]
2022	<b>J. Feldbrugge</b> , and N. Turok, "Existence of real time quantum path integrals", <i>Annals of Physics</i> (2023, R&R) <a href="#">arXiv:2207.12798</a> [ <a href="#">hep-th</a> ]

- 2022 D. Jow, U.-L. Pen, and **J. Feldbrugge**, “Regimes in astrophysical lensing: refractive optics, diffractive optics, and the Fresnel scale”, *Monthly Notices of the Royal Astronomical Society* (2022, R&R). [arXiv:2204.12004 \[astro-ph.CO\]](#)
- 2021 G. Wilding, K. Nevenzeel, R. van de Weygaert, G. Vegter, P. Pranav, B.J.T. Jones, K. Efstathiou, and **J. Feldbrugge**, “Persistent homology of the cosmic web. I: Hierarchical topology in  $\Lambda$ CDM cosmologies” *Monthly Notices of the Royal Astronomical Society* (2020) nr.507, 2968–2990. [arXiv:2011.12851 \[astro-ph.CO\]](#)
- 2020 **J. Feldbrugge**, and N. Turok, “Gravitational lensing of binary systems in wave optics,” *Physical Review Letters* (2020, R&R). [arXiv:2008.01154 \[gr-qc\]](#)
- 2019 **J. Feldbrugge**, M. van Engelen, R. van de Weygaert, P. Pranav, and G. Vegter, “Stochastic homology of Gaussian vs. non-Gaussian random fields: Graphs towards Betti numbers and persistence diagrams,” *Journal of Cosmology and Astroparticle Physics* (2019) no.9, 52–100. [arXiv:1908.01619 \[astro-ph.CO\]](#)
- 2019 A. Di Tucci, **J. Feldbrugge**, J.-L. Lehnert, N. Turok, “Quantum incompleteness of inflation,” *Physical Review D*, 100 (2019) no.6, 63517. [arXiv:1906.09007 \[hep-th\]](#)
- 2019 P. Pranav, R. van de Weygaert, G. Vegter, B.J.T. Jones, R.J. Adler, **J. Feldbrugge**, C. Park, T. Buchert, and M. Kerber, “Topology and geometry of Gaussian random fields I: on Betti numbers, Euler characteristic, and Minkowski functionals” *Monthly Notices of the Royal Astronomical Society*, 485 (2019) no.3, 4167–4208. [arXiv:1812.07310 \[astro-ph.CO\]](#)
- 2018 **J. Feldbrugge**, J.-L. Lehnert, and N. Turok, “Inconsistencies of the new no-boundary proposal,” *Universe*, 4 (2018), no.10, 100–115. [arXiv:1805.01609 \[hep-th\]](#)
- 2018 **J. Feldbrugge**, R. van de Weygaert, J. Hidding, and J. Feldbrugge, “Caustic skeleton & cosmic web,” *Journal of Cosmology and Astroparticle Physics* (2018) no.05, 27–81. [arXiv:1703.09598 \[astro-ph.CO\]](#)
- 2018 **J. Feldbrugge**, J. Lehnert, and N. Turok, “No rescue for the no boundary proposal: Pointers to the future of quantum cosmology,” *Physical Review D*, 97 (2018), no.2, 23509 [arXiv:1708.05104 \[hep-th\]](#)
- 2017 **J. Feldbrugge**, J.-L. Lehnert, and N. Turok, “No smooth beginning for spacetime,” *Physical Review Letters*, 119 (2017), no.17, 171301. [arXiv:1705.00192 \[hep-th\]](#)
- 2017 **J. Feldbrugge**, J.L. Lehnert, and N. Turok, “Lorentzian quantum cosmology,” *Physical Review D*, 95 (2017), no.10, 103508. [arXiv:1703.02076 \[hep-th\]](#)
- 2016 **J. Feldbrugge**, J. Hidding, and R. van de Weygaert “Statistics of caustics in large-scale structure formation,” *The Zeldovich Universe: Genesis and Growth of the Cosmic Web, Proceedings of the International Astronomical Union, IAU Symposium*, 308 (2016), 107–114. [arXiv:1412.5121 \[astro-ph.CO\]](#)
- 2013 R. van de Weygaert, G. Vegter, H. Edelsbrunner, B.J.T. Jones, P. Pranav, C. Park, W. Hellwing, B. Elderling, N. Kruithof, E.G.P. Bos, J. Hidding, **J. Feldbrugge**, E. ten Have, M. van Engelen, M. Caroli, and M. Teillaud, “Alpha, Betti and the megaparsec universe: On the topology of the cosmic web,” *Transactions on Computational Science XIV: Special Issue on Voronoi Diagrams and Delaunay Triangulation. Lecture Notes in Computer Science*, Vol. 6970. Springer Berlin Heidelberg (2013). [arXiv:1306.3640 \[astro-ph.CO\]](#)

## THESES

- 2019 **J. Feldbrugge**, “Path integrals in the sky: classical and quantum problems with minimal assumptions,” PhD thesis, Perimeter Institute, University of Waterloo, supervised by N. Turok. [Available online.](#)
- 2015 **J. Feldbrugge**, “Primordial non-Gaussianity and large-scale structure,” Part III Essay, University of Cambridge, supervised by P. Shellard and T. Giannantonio. [Available online.](#)
- 2014 **J. Feldbrugge**, “Statistics of caustics in large-scale structure formation,” Master thesis, University of Groningen, supervised by R. van de Weygaert, D. Roest, A.E. van Enter. [Available online.](#)
- 2012 **J. Feldbrugge** and M. van Engelen, “Analysis of Betti numbers and persistence diagrams of two-dimensional Gaussian random fields,” Bachelor thesis, University of Groningen, supervised by R. van de Weygaert, E. Pallante, G. Vegter. [Available online.](#)

## INVITED TALKS

- July 2023 Quantum Gravity 2023, Radboud University, Nijmegen, The Netherlands  
Presentation: On the existence of real-time path integrals
- July 2023 Theoretical physics group, University of New Brunswick, New Brunswick, Canada  
Presentation: On the existence of real-time path integrals
- March 2023 Optimal Transport Theory and Applications to Physics, Ecole Physique, Les Houches, France  
Presentation: Dissecting the cosmic web with caustics
- September 2022 2nd Roman Juskiwicz Symposium, Nicolaus Copernicus Astronomical Center, Warsaw, Poland  
Presentation: Dissecting the cosmic web with caustics
- June 2022 Information Universe 4, University of Groningen, Groningen, The Netherlands  
Presentation: Dissecting the cosmic web with caustics

May 2022	Cosmology seminar, Oxford University, Oxford, England Presentation: Dissecting the cosmic web with caustics
May 2022	UK Cosmo Meeting 2022, Newcastle University, Newcastle, England Presentation (keynote): Dissecting the cosmic web with caustics
October 2021	Higgs hour, University of Edinburgh, Edinburgh, Scotland Presentation: Interference, caustics and oscillatory integrals
May 2021	Seminar Universidad Nacional Autonoma de Mexico, Mexico city Presentation: Interference phenomena in lensing and quantum physics
May 2021	Sirius A symposium 2021: To infinity and beyond Presentation: The caustic skeleton of the cosmic web
October 2020	Quantum & Gravity Seminar, Radboud Universiteit, Nijmegen, The Netherlands Presentation: Lorentzian quantum cosmology
October 2020	Pusar group meeting, CITA, Toronto, Canada Presentation: Multi-plane lensing and gravitational binary lensing in wave optics
November 2019	Scintillometry 2019, Max Planck Institute for Radio Astronomy, Bonn, Germany Presentation: Oscillatory path integrals for radio astronomy
June 2018	2018 Rotman summer institute in philosophy of cosmology, Godrich, Canada Presentation: Lorentzian quantum cosmology (two lectures)
September 2016	CITA-PI day: Gravitational non-linear instability, CITA, Toronto, Canada Presentation: Shocks in the early universe and gravitational waves

#### CONTRIBUTED TALKS

February 2023	The Co-evolution of the Cosmic Web and Galaxies across Cosmic Time, Kavli Institute for Theoretical Physics, UC Santa Barbara, California, United States Presentation: Dissecting the cosmic web with caustics
July 2022	Cosmology from Home Presentation: Dissecting the cosmic web with caustics
March 2022	Cosmic Cartography 2022: Exploring the Cosmic Web and Large-Scale Structure, Kavli IPMU, Kashiwa, Japan Presentation: The caustic web and non-linear constrained Gaussian random fields
October 2021	Tuorla-Tartu meeting 2021, University of Turku, Turku, Finland Presentation: Caustic skeleton of the cosmic web
September 2020	Cosmology from home 2020, virtual conference on all aspects of cosmology. Presentation: The caustic skeleton of the cosmic web
March 2020	Topological statistics group meeting. Department of statistics at Carnegie Mellon University, Pittsburgh, United States Two presentations: Cosmology and topology I, and Cosmology and topology II
February 2020	The centre for the universe Waterloo Centre for Astrophysics day, Waterloo, Canada Presentation: Path integrals for radioastronomy and gravitational lensing II
February 2020	Cosmology group meeting, Perimeter Institute, Waterloo, Canada Presentation: The caustic skeleton of the cosmic web
January 2019	The cosmic web in the local universe, Lorentz center, Leiden, The Netherlands Presentation: The caustics skeleton of the cosmic web
October 2019	The Future of Astronomy, Waterloo Centre for Astrophysics, Waterloo, Canada Poster: Oscillatory path integrals for radio astronomy
September 2019	Theory group meeting, Carnegie Mellon University, Pittsburgh, United States Presentation: Interference and Picard-Lefschetz theory
September 2019	Simplicity III, Perimeter Institute, Waterloo, Canada Presentation: Fun with path integrals II
August 2019	Graduate student meeting, Perimeter Institute, Waterloo, Canada Presentation: Oscillatory integrals in the complex plane
June 2019	Probabilities in cosmology, University of Groningen, The Netherlands Presentation: Lorentzian beginnings of the universe
June 2019	The cosmic web: from galaxies to cosmology, Edinburgh, United Kingdom Presentation: Caustic skeleton of the cosmic web
May 2019	Cosmology group meeting Perimeter Institute, Waterloo, Canada Presentation: lenses and oscillatory integrals
May 2018	Albert Einstein Institute group meeting, Potsdam, Germany Presentation: Classical and weak trajectories

November 2017 Path integral of gravity, Perimeter Institute, Waterloo, Canada  
Presentation: Quantum incompleteness of inflation II

September 2017 Cosmology group meeting CITA, Canada  
Presentation: The instability of the no-boundary proposal

July 2017 Cosmic web day, University of Toronto, Toronto, Canada  
Presentation: The caustic skeleton of the cosmic web

May 2017 PI-day, Perimeter Institute, Waterloo, Canada  
Presentation: Lorentzian quantum cosmology

May 2017 Theory Canada 12, York University, Toronto, Canada  
Presentation: Lorentzian quantum cosmology

May 2017 Cosmology group meeting Perimeter Institute, Waterloo, Canada  
Presentation: Caustics in large-scale structure

May 2017 String cosmology group meeting Van Swinderen Institute, Groningen, Netherlands  
Presentation: Lorentzian quantum cosmology

April 2017 New Thoughts 3: About the universe and more, Ely, United Kingdom  
Presentation: Lorentzian quantum cosmology

April 2017 British gravity meeting 2017, University of Oxford, Oxford, United Kingdom  
Presentation: Lorentzian quantum cosmology

June 2016 Cosmology group meeting CITA, Canada  
Presentation: Statistics of caustics in large-scale structure

May 2016 Cosmology group meeting Perimeter Institute, Canada  
Presentation: Statistics of caustics in large-scale structure

March 2016 Statistics of extrema of large-scale structure, Lorentz center, Leiden, The Netherlands  
Presentation: Statistics of caustics in large-scale structure

June 2014 IAUS 308: The Zel'dovich universe, Tallinn, Estonia  
Presentation: Statistics of caustics in large-scale structure formation

October 2012 Structure of the cosmic web, Leibniz institute astrophysics, Potsdam, Germany  
Presentation: Analysis of Betti numbers and persistence diagrams in 2D GRFs

#### CONFERENCES AND WORKSHOPS (ATTENDED ONLY)

January 2023 New Directions in Theoretical Physics 4, University of Edinburgh, Edinburgh, Scotland

June 2022 Analogue Models of Gravity and Fluctuation-Induced phenomena, University of Edinburgh, Edinburgh, Scotland

June 2022 Online Workshop "Physics of the Early Universe"

January 2021 Cosmology 2021: the rise of field theory, University of Cambridge, Cambridge, The United Kingdom

October 2020 The information universe: What is the role of information in our Universe? University of Groningen, Groningen, The Netherlands

January 2020 First Dutch Mathematical Relativity Day, Radboud University Nijmegen, Nijmegen, The Netherlands

September 2019 Cosmological frontiers in fundamental physics 2019, Perimeter Institute, Waterloo, Canada

November 2018 Quantum universe, in celebration of Neil Turok's 60th birthday, Centro de Estudio Cientificos (CECs), Valdivia, Chile

August 2018 Cosmology and gravitational physics with lambda, Nordita, Stockholm, Sweden

June 2018 Scanning new horizons: Emergent space-time, black holes and quantum information, Van Swinderen Institute, Groningen, The Netherlands

January 2018 Gravity in the early universe, Princeton University, Princeton, United States

June 2017 Bounce scenarios in cosmology, Perimeter Institute, Waterloo, Canada

January 2017 Fundamentals of the universe, Van Swinderen Institute, Groningen, The Netherlands

January 2017 New directions in theoretical physics II, Higgs center for theoretical physics, Edinburgh, United Kingdom

October 2016 Midwest relativity meeting, Perimeter Institute, Waterloo, Canada

June 2016 Time in cosmology, Perimeter Institute, Canada

June 2016 Concepts and paradoxes in a quantum universe, Perimeter Institute, Canada

June 2016 Cosmological frontiers in fundamental physics 2016, Perimeter Institute, Canada

June 2015 Convergence, Perimeter Institute, Canada

April 2014 Quantum universe 4, University of Groningen, The Netherlands

March 2013 Quantum universe 3, University of Groningen, The Netherlands

## Advising

2023 - present	Advisor PhD project, Benjamin Hertzsch, University of Edinburgh, Edinburgh, United Kingdom: <b>Probing cosmological redshift surveys with the caustic skeleton</b>
2023 - present	Advisor master project, Vera Li, University of Edinburgh, Edinburgh, United Kingdom: <b>The caustic skeleton and redshift space distortions</b>
2023 - present	Co-advisor PhD project, Ariadna Metidieri, Radboud University, Nijmegen, The Netherlands: <b>Lensing of rotating stars and photons in wave optics</b>
2022 - present	Advisor master project, Joshua Jones, University of Cambridge, United Kingdom: <b>Monte Carlo integration of oscillatory integrals</b>
2022 - present	Co-advisor bachelor project, Yonatan Sklansky, University of Pennsylvania, United States: <b>Topology of multi-stream regions in <math>N</math>-body simulations</b>
2022 - 2023	Advisor master project, Yihan Yan, University of Waterloo, Canada: <b>Statistics of critical points in eigenvalue fields</b>
2020 - 2022	Co-advisor PhD project, Georg Wilding, University of Groningen, The Netherlands: <b>Topology of the two-dimensional cosmic web</b>
2021 - 2022	Advisor bachelor project, Yihan Yan, Waterloo University, Canada: <b>Homology of two- and three-dimensional Gaussian random fields</b>
2020 - 2021	Co-advisor PhD project, Varun Rustagi, University of Groningen, The Netherlands: <b>The caustic skeleton of the local universe</b>
2018 - 2022	Co-supervisor master project Kevin Bixerman, University of Groningen, The Netherlands: <b>The caustic skeleton of the local universe</b>

## Teaching

June 2023	School on Fundamentals of the Universe, Lorentz Center, Leiden, The Netherlands
June 2018	2018 Rotman summer institute in philosophy of cosmology, Godrich, Canada Two lectures on Lorentzian quantum cosmology
January 2018	PSI winter school, co-supervisor project 'Pair creation in de Sitter spacetime', Huntsville, Canada
2010 - 2015	Physics lecturer, exam training for secondary school students, UOCG Market BV
2013 - 2014	Developer of teaching material for exam training in physics, UOCG Market BV
2008 - 2014	Tutoring in mathematics and physics for secondary school students

## Service

2022	Co-organizer of the conference New Directions in Theoretical Physics 4 at the University of Edinburgh
2018 - present	Reviewer for Physical Review Letters (PRL), Physical Review D (PRD), the Journal of Cosmology and Astroparticle Physics (JCAP), the Journal of High Energy Physics (JHEP), and Universe.
2013 - 2014	Chairman of the professor Hendrik de Waard foundation
2012 - 2013	Treasurer of the professor Hendrik de Waard foundation
2011 - 2012	Member of the education committee mathematics, chairman of the student council
2010 - 2014	Guide at the Gratama telescope of the Blaauw observatory, Groningen, at stargazing events

## Languages

Dutch	Mother tongue	English	Fluent
German	Elementary	French	Elementary
Latin	Elementary		

## Programming experience

Mathematica	Fluent	C++	Fluent
Python	Moderate	Matlab	Moderate
Swift	Moderate	Julia	Elementary
Fortran	Elementary	R	Elementary