Kaibo Hu

Maxwell Institute &
School of Mathematics, University of Edinburgh
James Clerk Maxwell Building
Peter Guthrie Tait Road, Edinburgh, EH9 3FD

kaibo.hu@ed.ac.uk
kaibo.math@gmail.com
https://kaibohu.github.io

Employment

Royal Society University Research Fellow	
School of Mathematics, University of Edinburgh, UK	October 2023 -
Mathematical Institute, University of Oxford, UK	October 2022 - September 2023
Non-Stipendiary Postdoctoral Research Fellow	October 2021 - September 2023
Christ Church, Oxford, UK	
Hooke Research Fellow	January 2021 - September 2022
Mathematical Institute, University of Oxford, UK	
Postdoctoral Associate	August 2018 - January 2021
Department of Mathematics, University of Minnesota, USA	
Researcher	August 2017 - August 2018
Department of Mathematics, University of Oslo, Norway	

Education

2017.   Ph.D. in mathematics,
Beijing International Center for Mathematical Research, Peking University, China.
Advisor: Prof. Jinchao Xu
Thesis: *Finite Element Exterior Calculus for Multiphysics Problems*

2012.   B.S. in mathematics,
Nankai University, Tianjin, China.
Thesis: *Implementation of Nine Discontinuous Galerkin Methods for Convection-Dominated Convection-Diffusion Equations*

Visits (one week or more)

Peking University (2023), Queen Mary University of London (2023), TU Delft (2022), TU Wien (2023, 2022), Heidelberg University (2022), University of Vienna (2023, 2021), Isaac Newton Institute for Mathematical Sciences (2019), ETH Zürich (2019), University of Oslo (2021, 2017, 2015-2016), The Institute of Computational Mathematics and Scientific/Engineering Computing of Chinese Academy of Sciences (2019, 2017), Pennsylvania State University (2017, 2016).

Honors and Awards

[1] SIAM High Impact Article Collection, 2023.
— *"A Family of Finite Element Stokes Complexes in Three Dimensions"*, *K.Hu, Q.Zhang, Z.Zhang, SINUM 2022.*

[2] SIAM Computational Science and Engineering Early Career Prize, 2023.

[3] Royal Society University Research Fellowship, 2022-2027.

[4] Hooke Research Fellowship, Mathematical Institute, University of Oxford, UK. 2021.

[5] Non-Stipendiary Postdoctoral Research Fellowship, Christ Church, Oxford. 2021.

[6] Marie Skłodowska-Curie Individual Fellowship offer, EU, 2020.
— *evaluation on "excellence": 99%.*

[7] Invitation to the Conference celebrating *Acta Numerica*'s 30th birthday, Banach Center, Będlewo, Poland. June 14-19, 2021.
— *"...participation will be strictly by invitation: we hope for a good balance between leading experts in computational mathematics and the most brilliant representatives of the younger generation"*

[8] New World Mathematics Award, 2017,
— *for Ph.D thesis*

[9] Outstanding Youth Paper Prize, Beijing Society of Computational Mathematics, September 2016,
— *for the paper "Stable Finite Element Methods Preserving $\nabla\cdot\boldsymbol{B} = 0$ Exactly for MHD Models"*

[10] Student Paper Prize of East Asian SIAM, June 2016,
— *for the paper "Structure-preserving Finite Element Methods for Stationary MHD Models"*

[11] Peking University President Scholarship, 2014-2017.

Research Interests

I work on numerical analysis for partial differential equations (PDEs), particularly structure-preserving methods and finite element exterior calculus.

The vision of my current research includes:
- connections between homological algebra, geometry, numerical analysis and computation; geometric foundations of continuum mechanics,
- discretizations of PDEs and discrete theories (discrete geometry, discrete mechanics etc.),
- structure-preserving approaches for solving the Einstein equations in general relativity, with potential applications in computational astronomy and gravitational-wave sciences,
- advanced numerical methods (high order methods, preconditioning etc.) and applications (fluid and solid mechanics, magnetohydrodynamics etc.),
- scientific computing, computation of spectrum, localization.

Publications

Link to Google Scholar Profile.

[1] *A discrete elasticity complex on three-dimensional Alfeld splits*, Snorre H. Christiansen, Johnny Guzmán, Jay Gopalakrishnan and Kaibo Hu; accepted, Numerische Mathematik. arXiv:2009.07744 (2020).

[2] *Supersmoothness of the Alfeld split*, Michael S. Floater, Kaibo Hu; to appear in Springer IN-dAM Series "Approximation Theory and Numerical Analysis Meet Algebra, Geometry, Topology", edited by Martina Lanini, Henry Schenck. Carla Manni (2023).

[3] *Nonlinear elasticity complex and a finite element diagram chase*, Kaibo Hu; to appear in Springer INdAM Series "Approximation Theory and Numerical Analysis Meet Algebra, Geometry, Topology", edited by Martina Lanini, Henry Schenck. Carla Manni (2023).

[4] *Bounded Poincaré operators for twisted and BGG complexes*, Andreas Čap, Kaibo Hu; *accepted, Journal de Mathématiques Pures et Appliquées* (2023).

[5] *BGG sequences with weak regularity and applications*, Andreas Čap and Kaibo Hu; Accepted, Foundations of Computational Mathematics (2023).

[6] *Structure-preserving and helicity-conserving finite element approximations and preconditioning for the Hall MHD equations*, Fabian Laakmann, Kaibo Hu and Patrick E. Farrell; Journal of Computational Physics (2023).

[7] *Finite element systems for vector bundles: elasticity and curvature*, Snorre H. Christiansen and Kaibo Hu; Foundations of Computational Mathematics (2022).

[8] *A family of finite element Stokes complexes in three dimensions*, Kaibo Hu, Qian Zhang and Zhimin Zhang; SIAM Journal on Numerical Analysis (2022).

[9] *Spurious solutions for high order curl problems*, Kaibo Hu, Qian Zhang, Jiayu Han, Lixiu Wang, Zhimin Zhang; IMA Journal of Numerical Analysis (2022).

[10] *Partially discontinuous nodal finite elements for $H(\text{curl})$ and $H(\text{div})$*, Jun Hu, Kaibo Hu and Qian Zhang; Computational Methods in Applied Mathematics (2022).

[11] *Complexes from complexes*, Douglas N. Arnold and Kaibo Hu; Foundations of Computational Mathematics (2021).

[12] *Helicity-conservative discretization for incompressible MHD systems*, Kaibo Hu, Young-Ju Lee and Jinchao Xu; Journal of Computational Physics (2021).

[13] *Well-conditioned frames for finite element methods*; Kaibo Hu and Ragnar Winther; Journal of Computational Mathematics (2021).

[14] *Simple curl-curl-conforming finite elements in two dimensions*, Kaibo Hu, Qian Zhang and Zhimin Zhang; SIAM Journal on Scientific Computing (2020).

[15] *A characterization of supersmoothness of multivariate splines*, Michael S. Floater and Kaibo Hu; Advances in Computational Mathematics (2020).

[16] *Poincaré path integrals for elasticity*; Snorre H. Christiansen, Kaibo Hu and Espen Sande; *Journal de Mathématiques Pures et Appliquées* (2019).

[17] *Generalized Gaffney inequalities and discrete compactness for discrete differential forms*; Juncai He, Kaibo Hu and Jinchao Xu; *Numerische Mathematik* (2019).

[18] *Nonstandard finite element de Rham complexes on cubical meshes*; Andrew Gillette, Kaibo Hu and Shuo Zhang; *BIT Numerical Mathematics* (2019).

[19] *Convergence of a B-E based finite element method for MHD models on Lipschitz domains*; Kaibo Hu, Weifeng Qiu and Ke Shi; *Journal of Computational and Applied Mathematics* (2019).

[20] *Generalized finite element systems for smooth differential forms and Stokes' problem*, Snorre H. Christiansen and Kaibo Hu, *Numerische Mathematik* (2018).

[21] *Structure-preserving finite element methods for stationary MHD models*, Kaibo Hu and Jinchao Xu, *Mathematics of Computation* (2019).

[22] *Nodal finite element de Rham complexes*; Snorre H. Christiansen, Jun Hu and Kaibo Hu, *Numerische Mathematik* (2018).

[23] *Stable magnetic field-current finite element schemes for magnetohydrodynamics systems (in Chinese)*; Kaibo Hu and Jinchao Xu, *Science China Mathematics* (2016).

[24] *Robust preconditioners for incompressible MHD models*; Yicong Ma, Kaibo Hu, Xiaozhe Hu, and Jinchao Xu, *Journal of Computational Physics* (2016).

[25] *Stable finite element methods preserving $\nabla \cdot \boldsymbol{B} = 0$ exactly for MHD models*; Kaibo Hu, Yicong Ma and Jinchao Xu, *Numerische Mathematik*, (2017, appearing online 2016).

Preprints:

[26] *An exterior calculus framework for polytopal methods*, Francesco Bonaldi, Deniele A. Di Pietro, Jerome Droniou, Kaibo Hu; arXiv:2303.11093 (2023).

[27] *Discrete tensor product BGG sequences: splines and finite elements*, Francesca Bonizzoni, Kaibo Hu, Guido Kanschat and Duygu Sap; arXiv:2302.02434 (2023).

Talks

Conference/Workshop talks:

[1] Banff International Research Station (BIRS) "Homological Perspective on Splines and Finite Elements" workshop, University of British Columbia Okanagan (UBCO), Canada. May 2024. (Upcoming)

[2] Opening Conference of the CNRS Occitan Research Federation in Mathematics (OcciMath), LAMPS (Laboratory of Multidisciplinary Modeling and Simulations), University of Perpignan Via Domitia, France. April 2024. (Upcoming)

[3] Workshop: Theory and Numerics on Some Nonlinear PDEs; University of Oslo / online. October 2023. (Upcoming)

[4] ICIAM, Tokyo, Japan. August 2023.

[5] The 2023 International Workshop on Scientific Computing, Feng Kang Youth Forum on Scientific Computing (FKYF), The Institute of Computational Mathematics and Scientific/Engineering Computing of Chinese Academy of Sciences, Beijing, China. August 2023.

[6] PKU Mathematics Forum, Peking University, Beijing, China. July 2023.

[7] The 29th Biennial Numerical Analysis Conference, University of Strathclyde, Glasgow, UK. June 2023.

[8] SIAM Conference on Computational Science and Engineering (CSE23), Amsterdam, Netherlands. Feb/26-Mar/03/2023. (*plenary talk*)

[9] The 8th Workshop for Young Researchers in Scientific Computing, Chinese Academy of Sciences, China (online). Dec/7-8/2022.

[10] 56th Meeting of the Society for Natural Philosophy: Mechanics and Analysis, Pisa, Italy, Sep/21-23/2022.

[11] INdAM Meeting "Approximation Theory and Numerical Analysis meet Algebra, Geometry, Topology", Palazzone di Cortona, Italy, Sep/5-9/2022.

[12] 30 years of Acta Numerica conference at the Banach Centre in Będlewo, Poland, Jun/25-Jul/2/2022.

[13] MFO workshop "Hilbert Complexes: Analysis, Applications, and Discretizations", Oberwolfach, Germany, Jun/19-25/2022.

[14] Canadian Applied and Industrial Mathematics Society annual meeting, UBC Okanagan Canada (online), Jun/13-16/2022.

[15] European Finite Element Fair, Aalto University, Finland, Jun/3-4/2022.

[16] European Finite Element Fair, Inria, Paris, Sep/10-11/2022. (online)

[17] Mathematical and Computational Approaches for Solving the Source-Free Einstein Field Equations (virtual talk), ICERM, Brown University, USA, Oct/5-9/2020.

[18] The Second Conference on Scientific and Engineering Computing for Young Chinese Scientists, on the occasion of Professor Feng Kang's Centenary, Beijing, China, Aug/17-21/2019.

[19] International Multigrid Conference (IMG2019), Kunming, China, Aug/11-16/2019.

[20] International Conference on Scientific Computation and Differential Equations (SciCADE), Innsbruck, Austria, Jul/22-26/2019.

[21] International Congress on Industrial and Applied Mathematics (ICIAM 2019), Valencia, Spain, Jul/15-19/2019.

[22] Winther workshop in numerical methods, on the occasion of Ragnar Winther's 70th birthday, Oslo, Norway, Mar/14/2019.

[23] SIAM Minisymposium on Recent Developments in Numerical Methods for Fluids, Joint Mathematics Meeting of AMS and MAA, Baltimore, USA, Jan/16-19/2019.

[24] European Conference on Numerical Mathematics and Advanced Applications (ENUMATH2017), Voss, Norway, Sep/25-29/2017.

[25] Forum for youth scholars in computational mathematics, Peking University, Beijing, China, Jul/24-28/2017.

[26] Workshop on adaptive and multigrid methods for multiphysics problems, Beijing, China, Jun/23/2017.

[27] International Conference on Domain Decomposition, Svalbard, Norway, Feb/6-10/2017.

[28] Workshop on "Structure and scaling in computational field theories", Oslo, Norway, Oct/26-28/2016.

[29] 11th East Asia SIAM Conference, Macau, China, Jun/20-22/2016. (*paper prize talk*)

[30] 14th European finite element fair, Bonn, Germany, May/20-21/2016.

[31] 14th Copper Mountain Conference on Iterative Methods, Colorado, USA, Mar/20-25/2016.

[32] The 8th International Congress on Industrial and Applied Mathematics (ICIAM), Beijing, China, Aug/10-14/2015.

[33] Workshop on Geometry and Computation, Kunming, China, Aug/3-6/2015

[34] The 2st Peking University Computational Mathematics Student Forum, Beijing, China, Jul/11-12/2015

[35] Workshop on Numerical Methods for Elasticity and MHD Problems, Beijing, China, Dec/21/2014.

[36] 11th. World Congress on Computational Mechanics & 5th. European Conference on Computational Mechanics & 6th. European Conference on Computation Fluid Dynamics; Barcelona, Spain, July/25/2014.

[37] The 2nd Student Forum on Numerical Method of PDEs & the 1st Beijing Computational Mathematical Student Forum, Beijing, China, Jul/13/2014.

[38] The 1st Peking University Computational Mathematics Student Forum, Beijing, China, Nov/16/2013.

Colloquium/Seminar talks:

[39] Seminar at DAMTP, University of Cambridge, UK, Feb/2024. (Upcoming)

[40] Mathematics Seminar at the University of Dundee, UK. Oct/2023.

[41] Seminar at the Chinese University of Hong Kong (Shenzhen), Sep/2023.

[42] Seminar at Shanghai Jiao Tong University, Shanghai, China, Aug/2023.

[43] Seminar at University of Science and Technology of China, USTC, Aug/2023.

[44] Computational Mathematics and Applications Seminar, Mathematical Institute, University of Oxford, UK, Feb/23/2022.

[45] Imperial–UCL Numerics Seminar, London, UK, Feb/22/2022.

[46] Seminar at TU Delft, the Netherlands, Dec/16/2022.

[47] Gravity Seminar Series of STAG (gravity/string theory/mathematical physics group) of Mathematical Sciences, University of Southampton, Dec/8/2022.

[48] Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences, Beijing, China, Nov/2022.

[49] Seminar at University of Hong Kong, China, Oct/05/2022.

[50] Scientific Afternoon, Christ Church, University of Oxford, UK, Jul/15/2022.

[51] Culham Centre for Fusion Energy, UK, Apr/26/2022.

[52] Scientific Computing Seminar, Heidelberg University, Germany, Mar/21/2022.

[53] PDE Lunch Seminar, University of Oxford, UK, Feb/17/2022.

[54] North Meets South seminar, Mathematical Institute, University of Oxford, UK, Jan/28/2022.

[55] Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences, Beijing, China, Dec/14/2021. (online)

[56] Los Alamos National Lab, USA, Dec/8/2021.

[57] PDE seminar, Mathematical Institute, University of Oxford, UK, Aug/5/2021.

[58] General relativity journal club, Department of Physics, University of Oxford, UK, Jun/24/2021.

[59] Numerical analysis internal seminar, University of Oxford, UK, Feb/23/2021.

[60] Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences, Beijing, China, Dec/01-02/2020.

[61] Zurich Colloquium on Applied and Computational Mathematics, ETH Zürich, Switzerland, Oct/14/2020.

[62] Applied and Computational Mathematics seminar, Department of Mathematics, University of California, Irvine, USA, Apr/13/2020.

[63] Harmonic Analysis and Differential Equations (HADES) seminar, Department of Mathematics, University of Illinois at Urbana-Champaign, USA, Sep/27/2019.

[64] Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences, Beijing, China, Jul/17/2017.

[65] Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences, Beijing, China, Jun/22/2017.

[66] CCMA PDEs and Numerical Methods Seminar Series, Penn State University, USA, Mar/17/2016.

[67] Lecture of CAS SIAM Student Chapter, Chinese Academy of Sciences, Beijing, China, Nov/24/2014.

Professional Meetings/Workshops (Co-)organized

[1] Mini-symposium, *Finite element complexes and multivariate splines*, ICIAM, Tokyo, Japan, Aug/20-25/2023. Co-organizer, with Nelly Villamizar.

[2] Mini-symposium, *Structure-preserving discretization of Hilbert complexes*, the 29th Biennial Numerical Analysis Conference, University of Strathclyde, Glasgow, UK, Jun/27-30/2023. Co-organizer, with Deepesh Toshniwal.

[3] Scientific Afternoon, Christ Church, University of Oxford, UK, Apr/27/2023. Co-organizer, with Davide Spriano.

[4] Mini-symposium, *Exterior Calculus in Numerical Computing, Modeling, and Simulation*, SIAM Conference on Computational Science and Engineering (CSE23), Amsterdam, Netherlands. Co-organizer, with Ari Stern, James P. Fairbanks, Ingebord Gjerde.

[5] Mini-symposium, *Structure-preserving numerical methods for plasma models*, International Conference on Scientific Computation and Differential Equations (SciCADE2022), Reykjavík, Iceland, Jul/25-29/2022. Co-organizer, with Cecilia Pagliantini.

[6] Scientific Afternoon, Christ Church, University of Oxford, UK, Jul/15/2022. Co-organizer, with Davide Spriano.

[7] Mini-symposium, *Geometric numerical methods for fluids and electromagnetic fields*, International Multigrid Conference (IMG2019), Kunming, China, Aug/11-16/2019. Co-organizer, with Yajuan Sun.

[8] Mini-symposium, *Finite element exterior calculus and applications*, International Congress on Industrial and Applied Mathematics (ICIAM 2019), Valencia, Spain, Jul/15-19/2019. Co-organizer, with Shuo Zhang.

[9] Workshop on FEEC and High Order Methods; University of Oslo, Norway, Jun/04-06/2018. Co-organizer, with Ragnar Winther.

[10] The 3rd Student Forum on Numerical Method of PDEs & the 2nd Beijing Computational Mathematical Student Forum; Peking University, Beijing, China, Aug/18-19/2015.

[11] Workshop on Geometry and Computation, Kunming, China, Aug/3-6/2015. Co-organizer, with Gang Tian, Jinchao Xu, Xiao Zhang.

[12] The 2nd Student Forum on Numerical Method of PDEs & the 1st Beijing Computational Mathematical Student Forum; Peking University, Beijing, China, Jul/13/2014.

Teaching

- 2023 Trinity Term - 2023 Hilary Term: Calculus of Variations (Christ Church, tutorials + revision), MMSC dissertation projects (Mathematical Institute), University of Oxford.
- 2022 Michaelmas Term: BSP project (orthogonal polynomials), University of Oxford.
- 2022 Hilary Term: MMSC Modelling Case Studies (Turing mechanism), University of Oxford.
- 2021 Michaelmas Term: Finite element exterior calculus, University of Oxford.
- 2015 Spring: Real and functional analysis (for double degree students), TA, Peking University.
- 2014 Autumn: Topics in partial differential equations, TA, Peking University.
- 2014 Spring: Introduction to fluid mechanics, TA, Peking Univeristy.
- 2013 Autumn: Numerical algebra II, TA, Peking University.
- 2013 Spring: Differential Forms, Structure Preserving Discretization, and Multiscale Methods, TA, Peking University.
- 2013 Spring: Numerical analysis, TA, Peking University.

Supervision:

PhD

- Wouter Tonnon, ETH Zürich, 2023- (co-supervision with Ralf Hiptmair)
- Fabian Laakmann, University of Oxford, 2021-2022 (co-supervision with Patrick Farrell).

MSc dissertation

- 2023, 2021: MSc in Mathematical Modelling and Scientific Computing (MMSC), University of Oxford.

Services

- 2023-present, Coorganizer, Applied and Computational Mathematics (ACM) Seminars, Maxwell Institute.
- Reviewer for most major numerical analysis journals.
- Reviewer, scientific proposals for Banff International Research Station (BIRS).
- Dphil thesis examiner (University of Oxford, 2023).
- 2021-2023, Early Career Researchers (ECR) Committee Member, Mathematical Institute, University of Oxford.
- Judge for talk prizes, SIAM UKIE National Student Chapter Conference, June 2023, Oxford.