

COMPUTATIONAL SCIENCES MASTER PROGRAM

Starting every winter term at University of Cologne!
Application deadline: 15 July

// Computational Astro- and Space Physics

// Computational Biology

// Earth System Sciences

// Theoretical Chemistry

// Theoretical Condensed Matter Physics

Choose between 5 Specialization Areas!



WHY COMPUTATIONAL SCIENCES?



Answer New Questions in
Natural Sciences with
Computational Methods!

Gain In-Depth Knowledge:

- Modern Computational Methods
- Simulation and Modeling Tools
- Mathematical Methods for Data Science



DEGREE

Master of Science (M. Sc.)



APPLICATION

until July, 15th (winter semester)



LANGUAGE

English



DURATION

4 Semesters (2 years)



CREDITS

120 CP

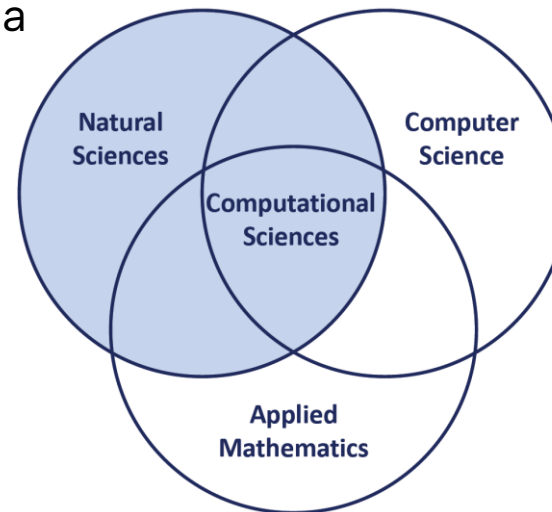


WHY COMPUTATIONAL SCIENCES?



The Master Degree in Computational Sciences

- provides you with the necessary skills to excel in a diverse range of professional areas that focus on the development of cutting edge data science and computational methods
- prepares you for positions in research or for a doctorate within your respective Area of Specialization with focus on computational methods
- qualifies you for leadership positions and specialized jobs within the IT sector



THE STUDY PROGRAM



UNIVERSITY
OF COLOGNE

Computational Sciences Master / Faculty of Mathematics and Natural Sciences

07.05.2024

CURRICULUM

Semester	Compulsory Modules total 18 CP	Mathematics/ Computer Science total 18 CP	Specialization total 78 CP	Supplementary Contents total 6 CP
1	Simulation & Modeling 1 9 CP	Elective Mathematics / Computer Science Area 18 CP	Specialization Area 30 CP	Suppl. Module 6 CP
2	Simulation & Modeling 2 9 CP			
3			Literature Seminar 6 CP	Project Work 12 CP
4			Master Thesis 30 CP	

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SIMULATION AND MODELING

Semester	Compulsory Modules total 18 CP	Mathematics/ Computer Science total 18 CP	Specialization total 78 CP	Supplementary Contents total 6 CP
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SIMULATION AND MODELING

Designed for CompSci Students – 2 Courses, 2 Semesters, 9 CP Each

In Semester 1 you learn:

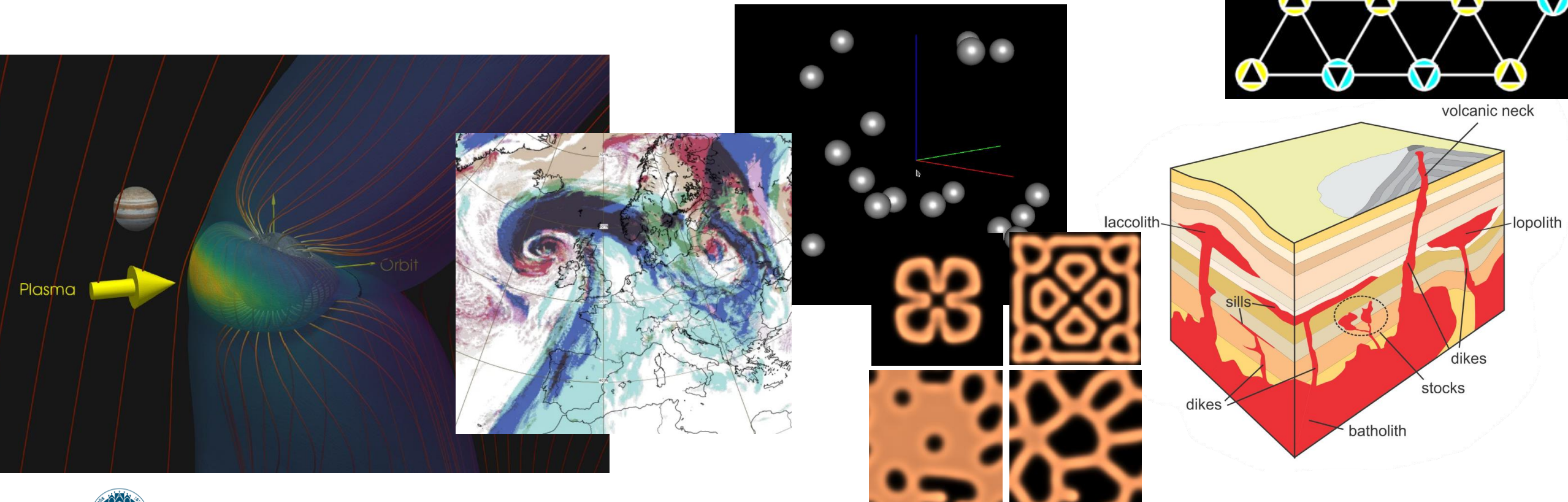
- Introduction to
 - (Mathematical) Modeling
 - Dynamical System Theory
 - Data Analysis and Processing
- Numerical Procedures to solve Systems of Linear Equations
 - Overview on Numerical Procedures
 - Critical Judgement of Model Simulations and Capacity of Model Development
 - Skillful Application of Numerical Procedures for Linear and Differential Equations and Further Data Analysis

In Semester 2 you learn:

- Introduction to
 - Ordinary and Partial Differential Equations
- Numerical Procedures to solve Differential Equations
- Initial and Boundary Conditions
- Spatial/Temporal Discretizations, Methods and Applications in Fluid Dynamics

SIMULATION AND MODELING – PRACTICAL TRAINING

- Each Semester: Work in a Team on Exciting Course Projects!
- In-Class Tutoring on Code-Development and Management with *git*
- Choose a Project from Various Fields in Natural Sciences:



THE SPECIALIZATION AREAS



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CHOOSE BETWEEN 5 SPECIALIZATION AREAS!

COMPUTATIONAL ASTRO-
AND SPACE PHYSICS



EARTH SYSTEM SCIENCES



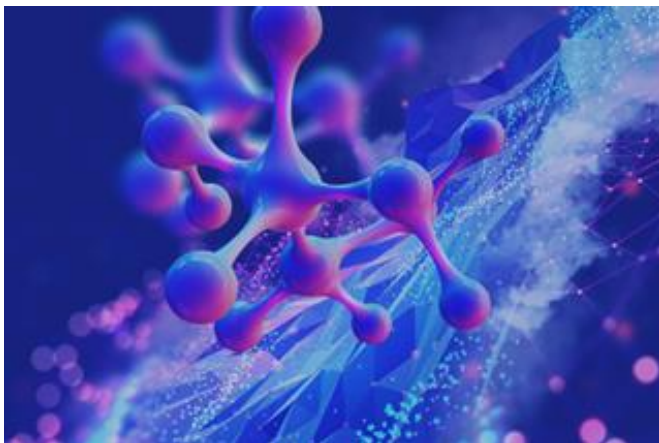
COMPUTATIONAL BIOLOGY



THEORETICAL CONDENSED
MATTER PHYSICS



THEORETICAL CHEMISTRY



COMPUTATIONAL ASTRO- AND SPACE PHYSICS

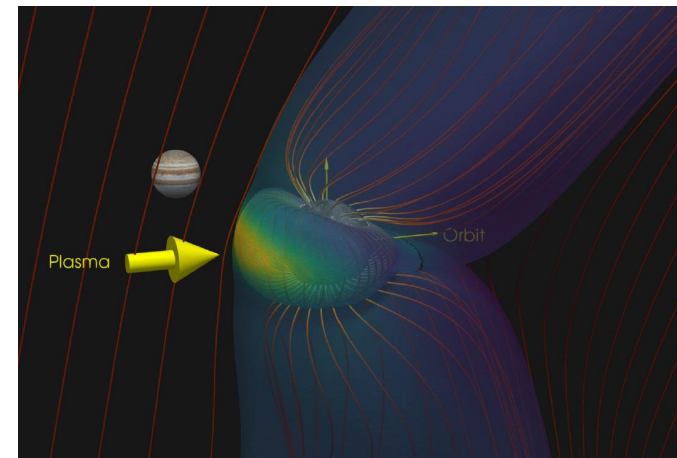


Why Computational Astro-/Space Physics?

- Complex Systems of plasmas around planetary/stellar bodies, which require numerical modeling
- Huge amount of data from telescopes and spacecraft missions
- Learn and apply computational and data science skills
- Modification and application of huge community codes on supercomputer
- Computational Sciences students have the right skills to work in astro physics or planetary groups

What you learn within the Master Program:

- *Advanced Astrophysics*
- *Space Physics*
- A wide range of elective courses



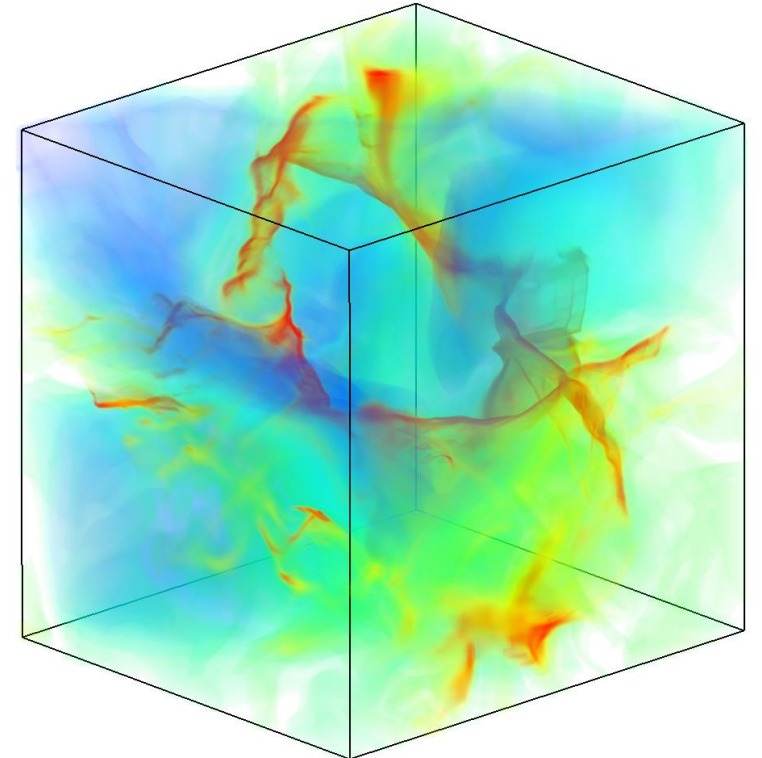
COMPUTATIONAL ASTRO- AND SPACE PHYSICS



- Research in Cologne:
 - Star Formation
 - Space Physics around planets and moons

After the master:

- Researcher in astrophysics or space and planetary sciences
- Data Scientist, Modeller



COMPUTATIONAL BIOLOGY



Why Computational Biology?

- Focus: Analysis and interpretation of (big) data
 - Human single nucleus: $3e9$ bytes text; $3e13$ cells/individual; $1e10$ individuals = $1e33$ bytes of (partially redundant) text
 - Human brain: $1e11$ neurons. $1e22$ interactions
 - $2e4$ genes/cell with on/off status. $2e4 = 1e6020$ possible combinations per unit time
- Skills needed: data handling (databases, compression, storage, parsing, encryption); data analysis (modelling&simulation, numerics, programming); data interpretation (statistics, machine learning, hypothesis generation and testing, prediction)
- Why You? Solid basis in quantitative methods; experience in models and simulations; expertise in translating numbers to meaning; cross-disciplinary competence

COMPUTATIONAL BIOLOGY



What you learn within the Master Program:

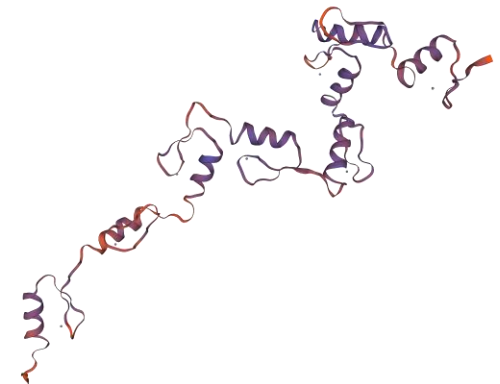
- *Computational Biology*
 - background in molecular biology (DNA/RNA/proteins), fundamental algorithms in bioinformatics, basics of network biology, statistical and ML methods applied to biological data
- *Practical in Computational Biology*
 - working with biological data, hands-on programming in R and/or Python, oral and written presentation of research results
- A wide range of elective courses, e.g.:
 - *population genetics and molecular evolution; forensics and statistical genetics*
 - *biomedical genetics and ageing research; systems biology; metabolism research; neurosciences*
 - *ecology and ecosystem biology*
 - *plant sciences*

COMPUTATIONAL BIOLOGY



Research in Cologne:

- CB groups at UoC in Genetics, Plant Sciences and Zoology;
- and at MPIs for Ageing Research, Metabolism Research and Plant Breeding Research
- Potential topic of master theses
 - "Mapping high-dimensional transcriptomic data into low-dimensional cellular states" (Beyer)
 - "Fitting a large-scale spiking network model of human cortex to depth-resolved resting-state functional MRI data" (v Alabada)



COMPUTATIONAL BIOLOGY



After the master:

- Academia:
 - Doctoral programmes in CB or related disciplines at major universities worldwide
 - Science support in technical positions as programmers or data analysts
 - Science support in administration or research coordination
- Outside academia:
 - Pharma and Biotech industries
 - Public sector, e.g. in disease and health monitoring, ecosystem management, urban planning
 - Scientific writing, public outreach and science communication

EARTH SYSTEM SCIENCES

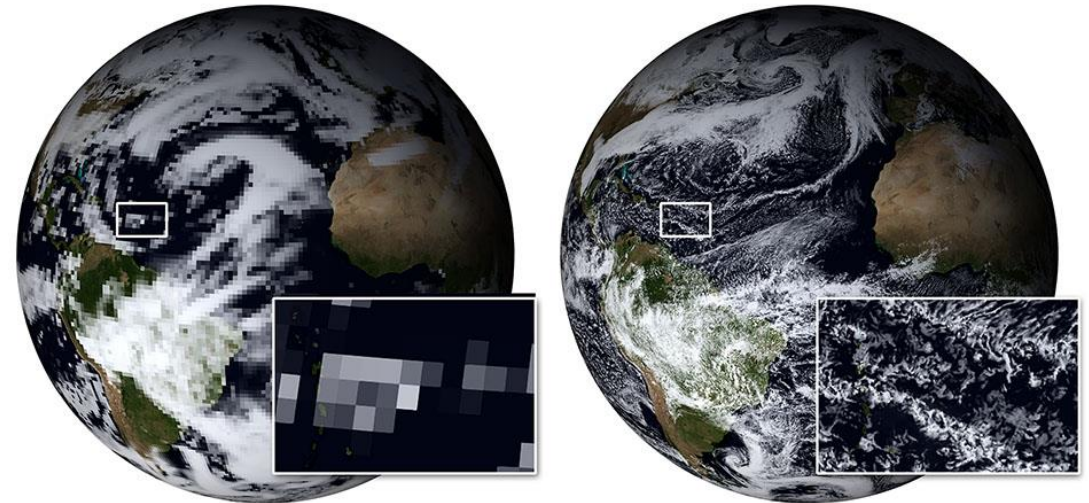


Why Earth System Sciences?

- The climate /weather system is an interdisciplinary challenge
- High demand on HPC and ML (performing simulations and analysis of data)
- High interest in including new ideas / methods – many open questions

What you learn within the Master Program:

- A wide range of elective courses , e.g.:
 - *Atmospheric Dynamics and Modeling*
 - *Experimental and numerical Mineralogy*
 - *Geophysics of the Solar System*



EARTH SYSTEM SCIENCES

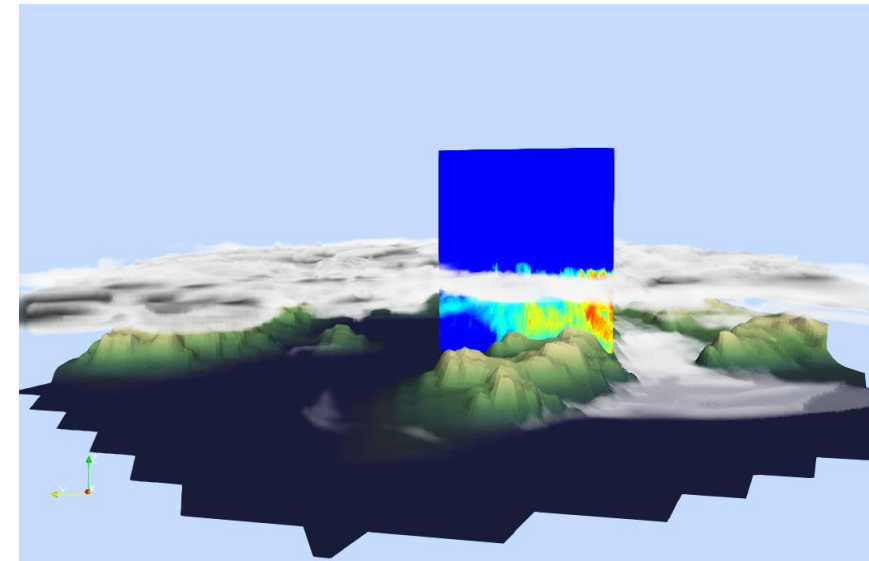


Research in Cologne:

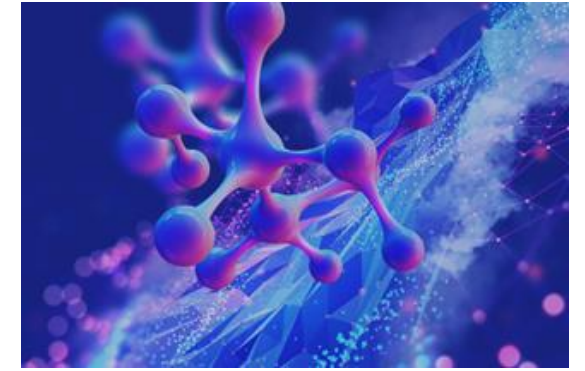
- Arctic Amplification – how can we improve the representation of specific processes (e.g. mixed-phase clouds) in our models?
- How can we improve predictions of extreme weather (e.g. thunderstorms or urban heat islands)?
- Clustering / analysis of large data sets – statistical measurements or satellite

After the master:

- A lot of research – at Universities, institutes, computing center
- Operational centers, renewable energy, insurances



THEORETICAL CHEMISTRY

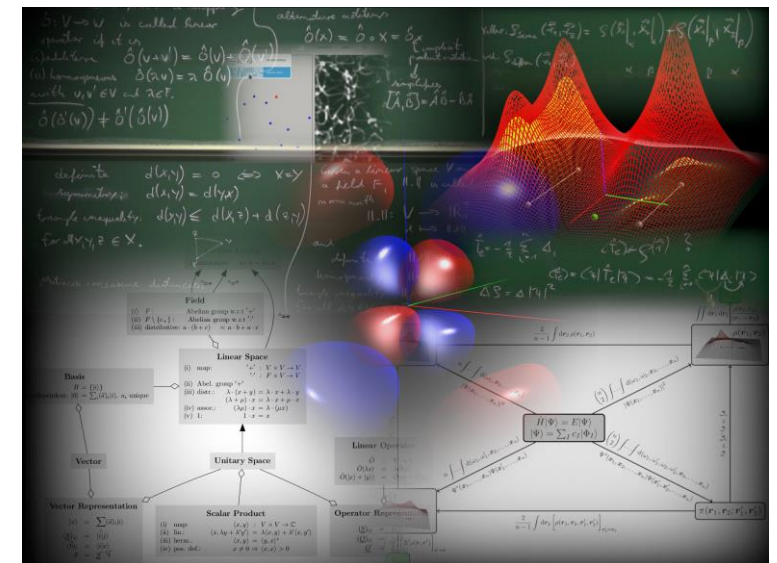


Why Theoretical Chemistry?

- Relation to Quantum Mechanics and Computer Science
- Theoretically: method development, computationally highly efficient antisymmetric tensor contractions and factorization, applied computations

What you learn within the Master Program:

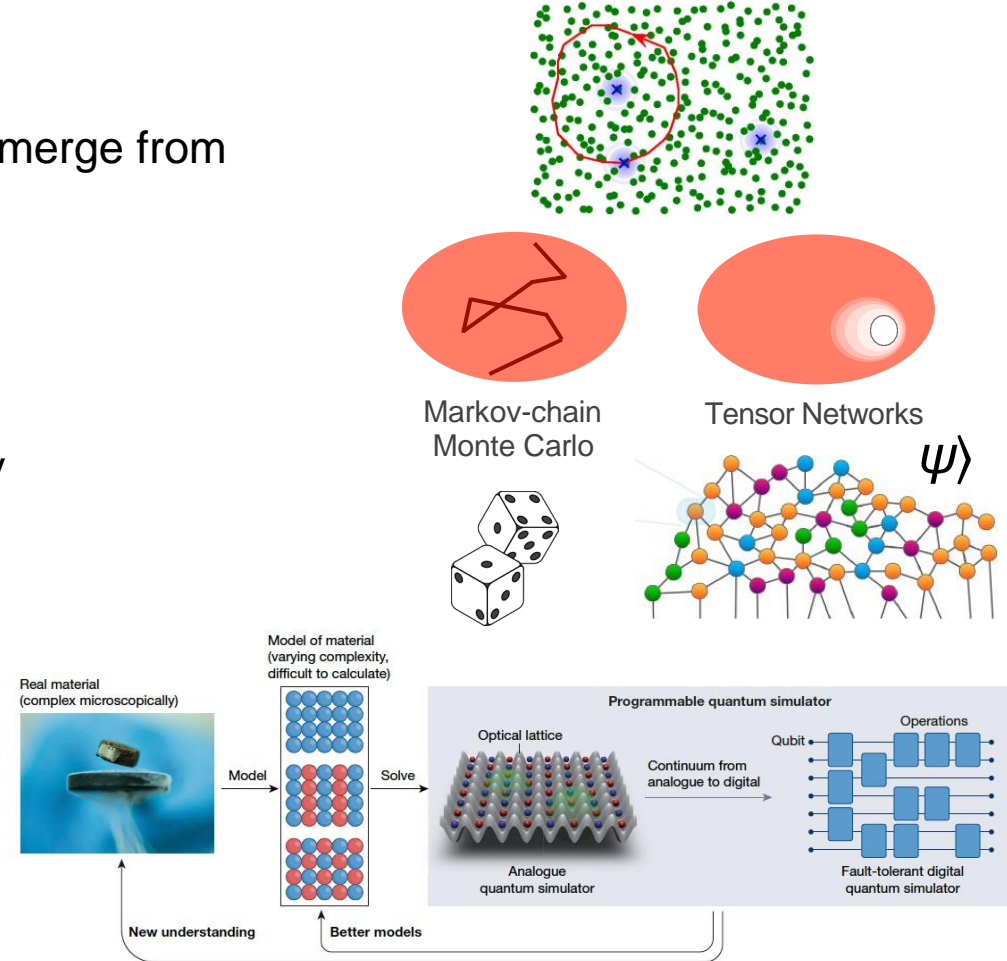
- *Advanced Theoretical Chemistry 1 + 2*
- A wide range of elective courses, e.g.:
 - *Programming in a Scientific Environment in C++*
 - Upcoming: *Computational Chemistry*
- See also: <https://www.tc.uni-koeln.de/people/hanrath/>



THEORETICAL CONDENSED MATTER PHYSICS

Why Theoretical Condensed Matter Physics?

- “More is different” — intriguing collective phenomena emerge from boring constituents
- Many-body curse of dimensionality: $\dim(H) \sim \exp(N) \dots$
 - clever algorithms can efficiently tame this complexity
- Quantum Simulation & Computation
 - use quantum as a new comp. tool!



THEORETICAL CONDENSED MATTER PHYSICS

What do you learn within the Master Program?

- *Advanced Quantum Mechanics*
- *Computational Many-Body Physics*
- *M-Lab Computational Physics* (hands-on num. exp.)
- Elective: *Adv. Stat. Phys. / Hydrodynamics / QFT I+II / Solid State Theory*



During the Master — Research in Cologne:

- investigating quantum circuits / contributing to quantum error correction
- devising quantum simulation schemes / variational quantum algorithms / ...
- porting ML techniques to CMT-numeric / ...

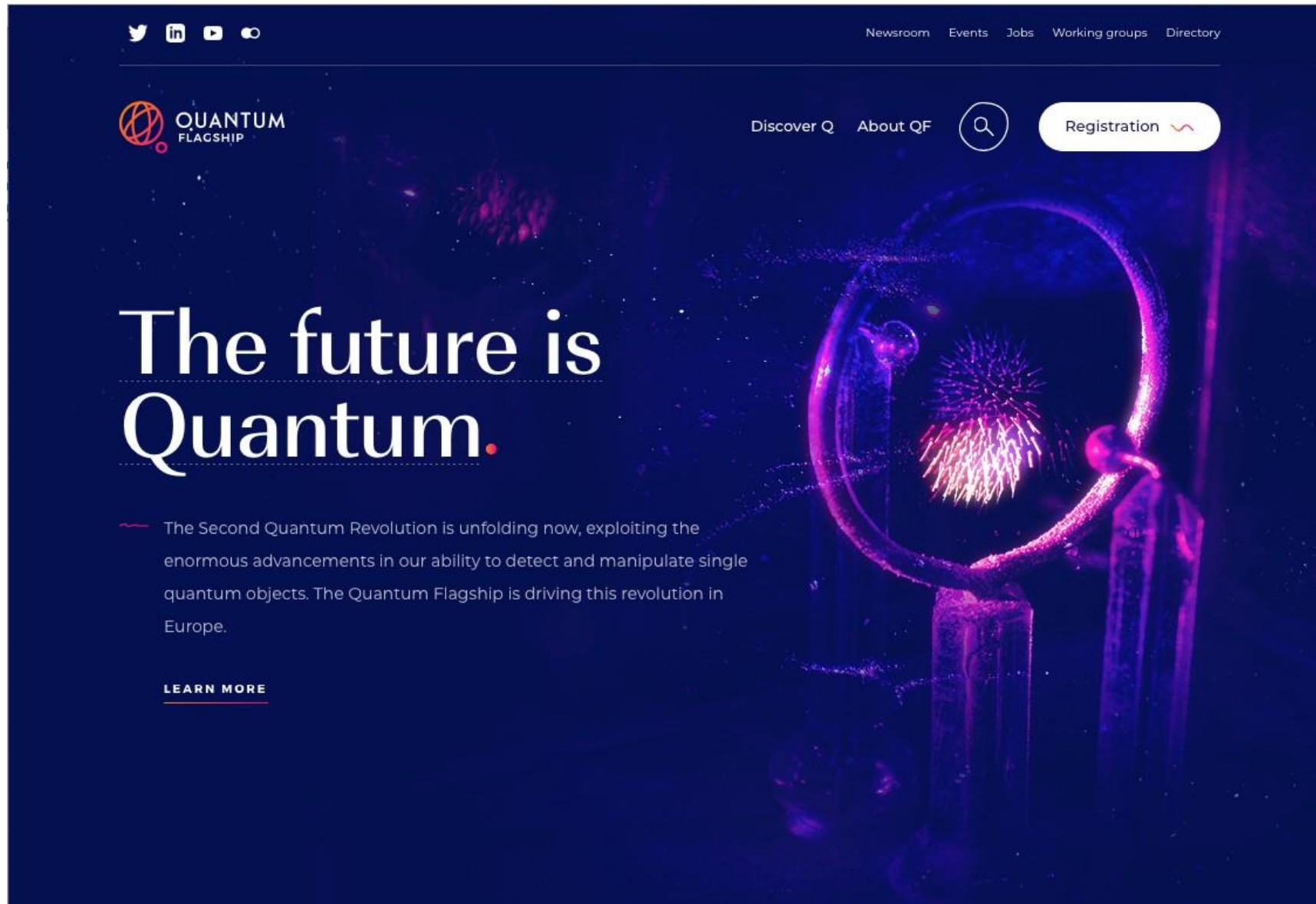


After the Master:

- academic path in universities and computing centers(!)
- industry is right now greedy on quantum people :-)



THEORETICAL CONDENSED MATTER PHYSICS

The image shows a screenshot of the Quantum Flagship website. The background is a dark blue space-themed image with a glowing quantum experiment setup. At the top left, there are social media icons for Twitter, LinkedIn, YouTube, and Instagram. At the top right, there are navigation links for Newsroom, Events, Jobs, Working groups, and Directory. Below the social media icons is the Quantum Flagship logo, which consists of a stylized orange and red globe icon followed by the text 'QUANTUM FLAGSHIP'. To the right of the logo are links for 'Discover Q' and 'About QF', a search icon, and a 'Registration' button with a small orange wave icon. The main content area features a large white headline 'The future is Quantum.' with a red underline under 'Quantum.'. Below the headline is a paragraph of text: 'The Second Quantum Revolution is unfolding now, exploiting the enormous advancements in our ability to detect and manipulate single quantum objects. The Quantum Flagship is driving this revolution in Europe.' At the bottom left of the main content area, there is a 'LEARN MORE' link with a red underline.

[Newsroom](#) [Events](#) [Jobs](#) [Working groups](#) [Directory](#)



[Discover Q](#) [About QF](#)



[Registration](#)

The future is Quantum.

The Second Quantum Revolution is unfolding now, exploiting the enormous advancements in our ability to detect and manipulate single quantum objects. The Quantum Flagship is driving this revolution in Europe.

[LEARN MORE](#)

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COMPUTATIONAL ASTRO-
AND SPACE PHYSICS



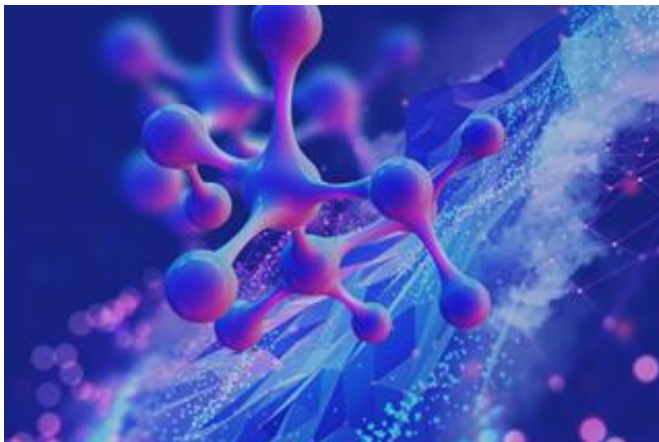
EARTH SYSTEM SCIENCES



COMPUTATIONAL BIOLOGY



THEORETICAL CHEMISTRY



THEORETICAL CONDENSED
MATTER PHYSICS



HOW TO APPLY?



UNIVERSITY
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ADMISSION REQUIREMENTS

Applicants require a **Bachelor of Science in the Natural Sciences, Mathematics, Computer Science** of at least 180 credit points (or an equivalent degree program) with the following achievements:

1. At least 21 CP in **Mathematics and/or Computer Science**
2. Knowledge of a **higher programming language** (e.g. Python, C++, Julia, ...)
3. At least 12 CP in one of the following fields
 - **Computational Astro-/Space Physics:** Theoretical Physics, Classical Mechanics, Electromagnetism
 - **Computational Biology:** Biology
 - **Earth System Sciences:** Geosciences, Meteorology or Physics
 - **Theoretical Chemistry:** Inorganic Chemistry, Quantum Chemistry
 - **Theoretical Condensed Matter Physics:** Quantum Physics and Statistical Physics

APPLICATION PROCESS

Submit your application electronically via the application portal of the University of Cologne KLIPS2.0:

<http://klips2.uni-koeln.de/>

- A start is only possible for the winter semester
- Application opens at the beginning of June
- **Deadline is 15 July** of the same year

Hand in the following **documents**:

- B. Sc. (or equivalent) certificate
- Transcript of records showing the awarded credits
- Curriculum Vitae
- Proof of proficiency in English level B2 (“Hochschulzugangsberechtigung“ is sufficient for German candidates)
- Proof of knowledge of a higher programming language (by e.g. certificate or bachelor thesis)
- Optional: Proof of other qualifications (e.g. professional practice, internships, stays abroad)

FREQUENTLY ASKED QUESTIONS (FAQ)

- 1. What if the curriculum of my Bachelor degree program involves less than the required 21 CP in Mathematics and/or Computer Sciences?**
 - You can achieve missing CP by taking additional courses, e.g. elementary courses of the Mathematics or Computer Science Bachelor program, or within the *Studium Integrale* (or similar)
- 2. How can I prove the knowledge of a higher programming language?**
 - A course that you attended (please refer to your ToR)
 - A project where you learned and applied a programming language, e.g. your Bachelor thesis or a course project (please provide a description of the project and how you used your programming skills)
 - Any other course where you have learned a higher programming language (please provide a certificate)
- 3. How many students can take the program each semester?**
 - The Computational Sciences master program currently has a capacity of 25 students each year

MORE INFO AND CONTACT



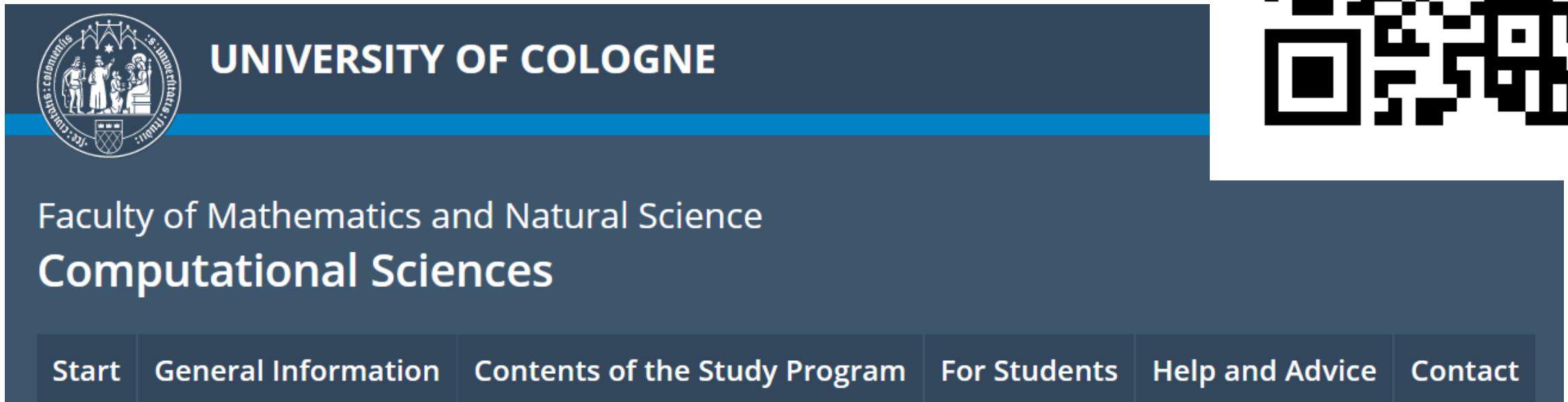
UNIVERSITY
OF COLOGNE

Computational Sciences Master / Faculty of Mathematics and Natural Sciences

07.05.2024

VISIT OUR WEBSITE

<https://computationalsciences.uni-koeln.de>



- Find all information about the study program and how to apply here
- These information slides are available on our website as well

Questions? Please don't hesitate to contact us:

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PEOPLE AND CONTACT



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UNIVERSITY
OF COLOGNE

THANK YOU FOR YOUR ATTENTION!

We Look Forward to Welcoming You to
THE COMPUTATIONAL SCIENCES MASTER PROGRAM
Next Winter Semester 2024/25 – Apply before 15 July!

