

NEWSLETTER

of the Work Group Mathematical Fluid Mechanics

Newsletter no. 15 (2022)

Paper based on Sandra's thesis accepted to JCP

The paper [J. Haack, C. Hauck, C. Klingenberg, M. Pirner, S. Warnecke: "Numerical schemes for a multi-species BGK model with velocity-dependent collision frequency"](#) has been accepted by the Journal of Computational Physics.

This is based on the work in [Sandra Warnecke's thesis](#). Being published in this high level journal is an acknowledgement of the quality of the work. The role of Cory Hauck was seminal in this project.



Cory Hauck

Amelie Gehring begins her Master thesis with us

Amelie Gehring will do her Master thesis with us. She will join our research effort on completing PDE models using measurements, our way to solve inverse problems.

Years of collaboration with Fritz Röpke bear fruit

The astrophysicist Fritz Röpke *and his group* simulate the evolution of stars. For this he needs to numerically solve the compressible Euler equations with a gravitational source term. This flow regime has two challenges: i.) the flow is near a stationary solution (near a hydrostatic equilibrium) and ii.) tends to be close to incompressible flow. We needed to find finite volume schemes that could handle both situations, that is find i.) well-balanced schemes and also find ii.) low Mach schemes. Even though we were eventually successful on both counts, it was only when we realized that

these two properties are closely intertwined and needed to be numerically treated accordingly ([Wasilij Barsukow's thesis](#) paved the way), that the astrophysical code of Fritz Röpke's team finally resulted in good simulations. To get to this point took many years, and we are there now!



Simulation of the flow inside a star, the flow is turbulent. The flow carries "fuel" from the interior of the star to its outside. This is a cut through a three dimensional flow simulation.

An overview article acknowledges our contribution

The Springer [Journal Living Reviews in Computational Astrophysics](#) has published an overview article on well-

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This semester I teach Mathematics of Machine Learning

This semester I am teaching a Master's course on the mathematical foundations of machine learning. This is jointly with Kathrin Hellmuth, who helps me with this course and is also doing the exercise section.

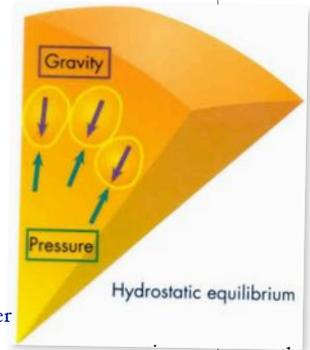
This is the first time such a course is being offered in our mathematics department. This resulted in about two-thirds of all our mathematics master students signing up for this course, showing the pent-up demand of our math students for such a course.

Our work group has a new poster

Our math dept. puts up posters of the various research groups. [Here](#) (and below) you can see the new poster of our work group.

balanced methods for the Euler equations with gravity, [see here](#). We have made many contributions to this subject because of our collaboration with Röpke (see the above article). This is reflected in this article by its viewpoint on the subject, close to ours.

a slice of a star, where pressure and gravity balance each other



Upcoming scientific conferences

Click the links to check where you might want to participate.

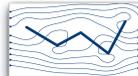
- Nov. 7 - 10, 2022: "[Numerical Methods for the Kinetic Equations of Plasma Physics](#)" (NumKin 2022) in Garching (near Munich), organized by Eric Sonnendrücker
- Nov. 14 - 18, 2022: "[Research School on Kinetic Theory](#)", in Luminy (near Marseille, France), organized by José Carillo, Markus Schmittchen and others
- Dec. 12 - 16, 2022: "[Kinetic and hyperbolic equations: modeling, analysis and numerics](#)", in Toulouse (France), organized among others by Francis Filbet

- Feb. 26 - March 3, 2023: "[SIAM Conference on Computational Sciences and Engineering or SIAM CSE23](#)", held in Amsterdam, organized among others by Hans deSterck
- March 29 - 31, 2023: "[4th European conference on Non-equilibrium gas flows](#)", in Eindhoven, Netherlands
- May, 2023 (either 8-12 or 22-26): "[Sharing Higher-order Advanced Research Know-how on Finite Volume \(SHARK-FV\)](#)" in Portugal, organized by Raphael Loubère and others
- June 26 - 30, 2023: "[NumHyp 2023 \(Numerical methods for hyperbolic problems\)](#)" in Bordeaux, France. organized by Christophe Berthon and others (the "important dates" on the website are in 2023)



- Sept. 4 - 8, 2023: "[European Conference on Numerical Mathematics and Advanced Applications \(ENUMATH\)](#)", in Lisbon, Portugal
- summer of 2024: "[International Conference on Hyperbolic Problems: Theory, Numerics and Applications \(HYP 2024\)](#)" in Shanghai, China, organized by Shi Jin

Mathematical Fluid Mechanics Christian Klingenberg



areas of research:

- completing PDE models using measurements, inverse problems, machine learning numerics
- structure preserving numerical schemes for Euler and MHD - applications in astrophysics
- kinetic and plasma theory and numerics
- theory of hyperbolic conservation laws

get to know our research

- by joining my seminars:

- Seminar angewandte Analysis (Bachelor)
- Seminar angewandte Analysis und numerische Mathematik (Master)
- Oberseminar mathematische Strömungsmechanik (open to all students)

- by attending my courses

- WS 22/23: Mathematics of Machine Learning (Master)

visitors to our work group

- Michael Dumbser (Italy)
- Alexander Kurganov (China)
- Eduard Feireisl (Prague)
- Praveen Chandrashekar (India)
- Philippe Helluy (Strasbourg)
- Nils-Henrik Risebro (Oslo)
- Gabriella Puppo (Italy)

topics of recent and of ongoing theses

doctoral theses:

- Lena Baumann: An efficient numerical approach applied to inverse problems for kinetic equations
- Jayesh Badwaik: moving mesh method in 2d & uncertainty quantification
- Claudius Birke: ideal magnetohydrodynamics, low Mach & well-balanced schemes, astrophysical applications - joint project with Fritz Röpke (Heidelberg)
- Kathrin Hellmuth: determine coefficients of PDE models by using measurements, inverse problems
- Eva Horlebein: convergence of approximate solutions to the compressible multi-dimensional Euler equations
- Sandra Warnicke: Numerical schemes for multi-species BGK equations based on a variational procedure
- Farah Kanbar: Asymptotic and Stationary Preserving Schemes for Kinetic and Hyperbolic Partial Differential Equations
- Andrea Thomann: Numerical methods for all-speed flows for the Euler eqns.

Master theses:

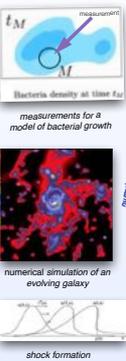
- Christine Barko: modeling flow in a Tokamak: the semi-Lagrange method for kinetic equations
- Veronika Mayerhofer: modeling flow in a network of channels, uncertainty quantification (jointly with Ulrik Fjordholm, Oslo)
- Kaja Jurak: the inverse problem for chemotaxis with birth and death rates in the Bayesian setting
- Marius Volpert: implementing an invariant domain preserving algorithm for the Euler equations that is low Mach
- Luis Kaiser: numerical wave propagation aided by machine learning
- Claudia Knorr: On numerical methods for astrophysical flow (numerical parameter study with the astrophysics code by Fritz Röpke)
- Carolin Apter (aka Praktikantin bei der Deutschen Bank): Stochastische Modelle zur Bewertung von Zinsderivaten

Bachelor theses:

- Sophie Lauer: singuläre Grenzwerte der kompressiblen Eulergleichungen
- Christopher Schäfer: gage-gravity duality, anti-de Sitter / conformal field theory correspondence
- Nadia Jammal: On modeling Tsunami waves



for more information, visit my homepage:



$$\begin{aligned} \partial_t \rho + \nabla \cdot (\rho \mathbf{u}) &= 0, \\ \partial_t (\rho \mathbf{u}) + \nabla \cdot (\rho \mathbf{u} \mathbf{u}) + \nabla P &= \rho \mathbf{a}, \\ \partial_t (\rho E) + \nabla \cdot (\rho E \mathbf{u} + P \mathbf{u}) &= \rho \mathbf{u} \cdot \mathbf{a}. \end{aligned}$$

the Euler equations of compressible gas dynamics w. gravity

professors closely associated with us:

- Fritz Röpke (astrophysics)
- Qin Li (Madison, Wisc. USA)
- Lukas Einkemmer (Innsbruck, Österreich)
- Matthias Maier (Texas A&M, USA)

postdoc:

Marlies Pirner

doctoral students:

- Lena Baumann
- Claudius Birke
- Kathrin Hellmuth
- Eva Horlebein
- Jayesh Badwaik

writing their Master thesis:

- Christine Barko
- Maritz Beck
- Yu-Chen Cheng
- Gerhard Dill
- Amelie Gehring
- Kaja Jurak
- Luis Kaiser
- Veronika Mayerhofer
- Sebastian Schmidt
- Marius Volpert

writing their Bachelor thesis:

- Sophie Lauer
- Christopher Schäfer
- Tim Winkler