FVCA9 program - Day 1

# Time Monday (June 15)

## Discretizations on Polytopal Meshes

**09:15** Jerome Droniou

*Interplay between diffusion anisotropy and mesh skewness in Hybrid High-Order schemes*

*In this talk, we will explore the effect of mesh skewness on the accuracy of the standard Hybrid High-Order (HHO) method for anisotropic diffusion equations. The skewness we consider enables us in particular to consider meshes with elements that become elongated as the mesh is refined - which means that such meshes are not "regular" in the standard sense. We will present an error estimate that precisely tracks the dependency with respect to the elements skewness and the diffusion anistropy. This estimate is designed to demonstrate an interplay between these two features. Numerical tests will also be presented to explore this interplay. Most of these tests show that, except for the lowest degree, the HHO method seems particularly robust with respect to highly skewed meshes or highly anisotropic diffusion.*

**10:00** Coffee breakout

**10:20** Talk 1 – Paper 009 (Chave, Di Pietro, Lemaire)

*A three-dimensional Hybrid High-Order method for magnetostatics*

**10:40** Talk 2 – Paper 048 (Klemetsdal, Møyner, Raynaud, Lie)

*A Comparison of Consistent Discretizations for Elliptic Problems on Polyhedral Grids*

**11:00** Discussion & Lunch break

## Adaptive Methods

**13:15** Martin Vohralík

*A posteriori error estimates with inexact solvers and recovering mass balance in any situation*

*We develop an a posteriori error estimate for lowest-order locally conservative methods on meshes consisting of general polytopal elements. The evaluation of the estimate is inexpensive since it merely consists in some matrix-vector multiplications on each mesh element. A fully computable guaranteed bound on the overall error is obtained, and the individual error components are identified (algebraic solver error, linearization solver error, space discretization error, time discretization error). Even in presence of inexact algebraic or linearization solvers and for advanced applications like multi-phase multi-compositional flows in porous media, is shown that that the procedure used to estimate the error from the inexact solvers can lead to a full elementwise mass conservation (typically a feature of finite-volume-type discretizations with exact solvers only).*

**14:00** Coffee breakout

**14:20** Talk 3 – Paper 004 (Giesselmann, Joshi)

*Model adaptation of balance laws based on a posteriori error estimates and surrogate fluxes*

**14:40** Talk 4 – Paper 045 (Wieners, Dörfler, Ziegler)

*Space-time discontinuous Galerkin methods for linear hyperbolic systems*

**15:00** Coffee breakout

**15:30** Poster Session

Paper 005 (Cheng) - *Post-processing of fluxes for finite volume methods for elliptic problems*

Paper 021 (Andreianov, Sylla) - *A macroscopic model to reproduce self-organization at bottlenecks*

Paper 024 (Linke, Merdon) - *On the significance of pressure-robustness for the space discretization of incompressible high Reynolds number flows*

Paper 027 (Mokhtari, Davit, Latché, Loubens, Quintard ) - *A Marker-and-Cell scheme for viscoelastic flows on nonuniform grids*

Paper 029 (Görtz, Birken) - *On the convergence rate of the Dirichlet-Neumann iteration for coupled Poisson problems on unstructured grids*

Paper 030 (Brunel, Herbin, Latché) - *MUSCL discretization for fluid flows convection operator on staggered meshes*

Paper 033 (Gallouët,Herbin, Latché, Nasseri) - *A second order consistent MAC scheme for the shallow water equations on non uniform grids*

Paper 040 (Goudon, Krell, Lissoni) - *Convergence study of a DDFV scheme for the Navier-Stokes equations arising in the domain decomposition setting*

Paper 041 (Brenner) - *Acceleration of Newton's method using nonlinear Jacobi preconditioning*

Paper 043 (Ziggaf, Boubekeur, El Mahi) - *The FVC scheme on unstructured meshes for the two-dimensional Shallow Water Equations*

Paper 044 (Bradji) – *A new gradient scheme of a time fractional Fokker--Planck equation with time independent forcing and its convergence analysis*

Paper 046 (Boon, Nordbotten) - *Convergence of a TPFA Finite Volume Scheme for Mixed-Dimensional Flow Problems*

Paper 055 (Bassetto, Cancès, Enchéry, Tran) - *Robust Newton solver based on variable switch for a finite volume discretization of Richards equation*

Paper 066 (EL Mahi, Moumna, Benkhaldoun, Kissami) - *Application of an unstructured finite volume method to the shallow water equations with porosity for urban flood modelling*

**18:00** Free time

FVCA9 program - Day 2

# Time Tuesday (June 16)

**Seminconductor Applications**

09:15 Marianne Bessemoulin-Chatard

*Numerical schemes for semiconductors energy-transport models*

*We introduce some finite volume schemes for unipolar energy-transport models. Using a reformulation in dual entropy variables, we can show the decay of a discrete entropy with control of the discrete entropy dissipation.*

10:00 Coffee breakout

10:20 Talk 5 – Paper 022 (Cances, Gaudeul)

*Entropy diminishing finite volume approximation of a cross-diffusion system*

10:40 Talk 6 – Paper 026 (Kanter, Koprucki)

*Non-isothermal Scharfetter-Gummel scheme for electro-thermal transport simulation in degenerate semiconductors*

11:00 Discussion & Lunch break

**Flow in Fractured Porous Media**

13:15 Alessio Fumagalli

*Mixed-virtual element methods for discrete fracture matrix models. An application to reactive transport.*

*In this presentation we introduce the mixed-virtual element method for applications in underground problems, in particular for the numerical solution of flow problem via Darcy law. The method is extended to the mixed-dimensional case, getting the possibility to solve flow in fractured porous media, where the fractures and their intersections are considered as objects of lower dimension. We show the effectiveness of the proposed approach for complex geometries arising from complex fracture networks. The second part of the presentation is devoted to introduction of a reactive transport in a fractured porous media. Chemical reactions may alter the local properties of the porous media as well as the fracture walls, changing the flow path and possibly occluding some portions of the fractures or zones in the porous media. The mixed-virtual element method is employed in this case for complex fracture networks to overcome some of the computational challenges.*

14:00 Coffee breakout

14:20 Talk 7 – Paper 032 (Bonaldi, Brenner, Droniou, Masson)

*The Gradient Discretisation Method for Two-phase Discrete Fracture Matrix Models in Deformable Porous Media*

14:40 Talk 8 – Paper 016 (Burbulla, Rhode)

*A Fully Conforming Finite Volume Approach to Two-Phase Flow in Fractured Porous Media*

15:00 Coffee breakout

15:30 Poster Session

Paper 003 (Farrell, Peschka) - *Challenges in drift-diffusion semiconductor simulations*

Paper 006 (Bringedal) - *A conservative phase-field model for reactive transport*

Paper 008 (Caucao, Li, Yotov) - *A cell-centered finite volume method for the Navier-Stokes/Biot model*

Paper 015 (Stefansson, Berre, Keilegavlen) - *Finite volume discretisation of fracture deformation in thermo-poroelastic media*

Paper 018 (Eggenweiler, Rybak) - *Interface Conditions for Arbitrary Flows in Coupled Porous-Medium and Free-Flow Systems*

Paper 025 (Fuhrmann, Doan, Glitzky, Liero, Nika) - *Unipolar Drift-Diffusion Simulation of S-shaped Current-Voltage Relations for Organic Semiconductor Devices*

Paper 031 (Bradji) - *A new optimal* $L^\infty(H^1)$ *– error estimate of a SUSHI scheme for the time fractional diffusion equation*

Paper 034 (Sargado) - *A control volume finite element formulation with subcell reconstruction for phase-field fracture*

Paper 036 (Brenner, Masson, El Houssaine) - *A robust VAG scheme for a two-phase flow problem in heterogeneous porous media*

Paper 052 (Cancès, Nabet) - *Energy stable discretization for two-phase porous media flows*

Paper 053 (Choquet, Diedhiou, Nasser El Dine) - *Numerical analysis of a finite volume scheme for the optimal control of groundwater pollution*

Paper 059 (Jaust, Weishaupt, Mehl, Flemisch) - *Partitioned coupling schemes for free-flow and porous-media applications with sharp interfaces*

Paper 063 (Nikitin, Yanbarisov) - *Monotone embedded discrete fracture method for the two-phase flow model*

Paper 072 (Knodel, Kräutle, Knabner) - *Global implicit solver for multiphase multicomponent flow in porous media with multiple gas phases and general reactions*

18:00 Free time

# Time Wednesday (June 17)

**Theoretical Aspects of Compressible Flow**

09:15 Maria Lukácová

*K-convergence of finite volume solutions of the Euler equations*

*We will present our recent results on the convergence analysis of suitable finite volume methods for multidimensional Euler equations of gas dynamics. Assuming only that numerical solutions stay in a gas non-degenerate region we will show that a sequence of numerical solutions converges weakly to a weak dissipative solution. The weak-strong uniqueness principle implies the strong convergence of numerical solutions to the classical solution as long as it exists. On the other hand, if the classical solution does not exist we apply a new concept of the so-called K convergence and show how to compute effectively the observable quantities of a space-time parametrized measure generated by numerical solutions. Consequently, we derive the strong convergence of the empirical averages of numerical solutions to a weak dissipative solution.*

10:00 Coffee breakout

10:20 Talk 9 – Paper 019 (Bonelle, Ern, Milani)

*Compatible Discrete Operator schemes for the steady incompressible Stokes and Navier–Stokes equations*

10:40 Talk 10 – Paper 023 (Linke, Merdon)

*Well-balanced discretisation for the compressible Stokes problem by gradient-robustness*

11:00 Discussion & Lunch break

**Complex Geometries**

13:15 Sandra May

*Time-dependent conservation laws on cut cell meshes and the small cell problem*

*Cut cells methods have been developed in recent years for computing flow around bodies with complicated geometries. Cut cell methods cut the flow body out of a regular Cartesian grid resulting in so called cut cells. Cut cells can have irregular shape and may be very small. For solving time-dependent conservation laws on cut cell meshes, probably the biggest problem one has to face is the small cell problem: standard explicit schemes are not stable if the time step is chosen based on the size of the background cells. Therefore, special schemes must be developed. In the first part of this talk, we discuss the small cell problem in detail and summarize several existing solution approaches in the context of both finite volume (FV) schemes and discontinuous Galerkin (DG) schemes. In the second part, we present our two fundamentally different solution approaches for overcoming the small cell problem: the FV based mixed explicit implicit scheme, developed in collaboration with Berger (J. Sci. Comput. 71, pp. 919-943, 2017), and the DG based Domain-of-Dependence (DoD) stabilization, joint work with Engwer, Nüßing, and Streitbürger (arXiv:1906.05642).*

14:00 Coffee breakout

14:20 Talk 11 – Paper 065 (Kerkmann, Helzel)

*An Active Flux Method for Cut Cell Grids*

14:40 Talk 12 – Paper 014 (Hahn, Mikula, Frolkovič, Balazovjech, Basara)

*Cell-centered finite volume method for regularized mean curvature flow on polyhedral meshes*

15:00 Coffee breakout

17:00 Conference hangout

## Time Thursday (June 18)

**Emerging Methods in Modeling and Simulation – Part 1**

09:15 Mario Ohlberger

*Advances in model order reduction beyond offline/online splitting*

*Model order reduction has become a mature technique for simulation of large classes of parameterized Systems. However, several challenges remain for problems where the solution manifold of the parameterized system cannot be well approximated by linear subspaces. While the online efficiency of these model reduction methods is very convincing for problems with a rapid decay of the Kolmogorov n-width, there are still major drawbacks and limitations. Most importantly, the construction of the reduced system in the offline phase is extremely CPU-time and memory consuming. For practical applications, it is thus necessary to derive model reduction techniques that do not rely on a classical offline/online splitting but allow for more flexibility in the usage of computational resources. A promising approach with this respect is model reduction with adaptive enrichment. In this talk we investigate model reduction with adaptive basis enrichment for the solution of PDE constrained optimization problems.*

10:00 Coffee breakout

10:20 Talk 13 – Paper 075 (Egger, Philippi)

*A hybrid discontinuous Galerkin method for transport equations on networks*

10:40 Talk 14 – Paper 058 (Both, Nordbotten, Radu)

*Free energy diminishing discretization of Darcy-Forchheimer flow in poroelastic media*

11:00 Discussion & Lunch break

**Stochastic PDEs**

13:15 Per Pettersson

*Uncertainty quantification for nonsmooth problems*

*This talk features some probabilistic and statistical methods for forward uncertainty propagation when the quantity of interest (e.g., PDE solution) is a nonsmooth function of the input parameters. In particular, this is often the case for nonlinear conservation laws. The first part of the talk is devoted to probabilistic projection methods based on spectral expansions, i.e., stochastic Galerkin methods. Numerical methods used for the corresponding deterministic problems can often be generalized to the stochastic setting, but the extension can be nontrivial. Numerical challenges and solutions will be surveyed with examples from fluid dynamics.*
*The second part of the talk features statistical methods based on sampling, i.e. Monte Carlo methods.Standard Monte Carlo methods are very robust but converge slowly with the number of samples.We introduceadaptive and dynamic stratification methodstargeted to nonsmooth problems, resulting in significant speedup compared to standard Monte Carlo.*

14:00 Coffee breakout

14:20 Talk 15 – Paper 049 (Brencher, Barth)

*Hyperbolic conservation laws with stochastic discontinuous flux functions*

14:40 Talk 16 – Paper 047 (Holm, Sætra, Brodtkorb)

*Data Assimilation for Ocean Drift Trajectories Using Massive Ensembles and GPUs*

15:00 Coffee breakout

15:30 Poster Session

Paper 002 (Zurek, Jüngel) - *A finite-volume scheme for a cross-diffusion model arising from interacting many-particle population systems*

Paper 007 (Chainais-Hillairet, Herda) - *$L^\infty$ bounds for numerical solutions of noncoercive convection-diffusion equations*

Paper 010 (Chainais-Hillairet, Krell) - *Exponential decay to equilibrium of nonlinear DDFV schemes for convection-diffusion equations*

Paper 011 (El Keurti, Rey) - *Finite Volume Method for a System of Continuity Equations Driven by Nonlocal Interactions*

Paper 012 (Franck, Navoret) - *Semi-implicit two-speed Well-Balanced relaxation scheme for Ripa model*

Paper 017 (Colas, Ferrand, Hérard, Hurisse, Quibel, Le Coupanec) - *A Numerical Convergence Study of some Open Boundary Conditions for Euler Equations*

Paper 020 (Bradji, Benkhaldoun) - *Note on the convergence of a finite volume scheme for a second order hyperbolic equation with a time delay in any space dimension*

Paper 035 (Calgaro, Creusé) - *A finite volume method for a convection-diffusion equation involving a Joule term*

Paper 037 (Hélie, Helluy, Franck, Navoret) - *Kinetic over-relaxation method for the convection equation with Fourier solver*

Paper 038 (Gerstenberger, Burbulla, Kröner) - *Discontinuous Galerkin method for incompressible two-phase flows*

Paper 051 (Kozhanova, Goncalves, Hoarau) - *High-order numerical methods for compressible two-phase flows*

Paper 056 (Nguepi, Braconnier, Preux, Tran, Berthon) - *A relaxation method for the simulation of possibly non-hyperbolic polymer flooding models with inaccessible pore volume effect*

Paper 069 (Cancès, Chainais-Hillairet, Gaudeul, Fuhrmann) - *On four numerical schemes for a unipolar degenerate drift-diffusion model*

Paper 074 (Batteux, Laminie, Latché, Poullet) - *3-dimensional particulate flow modelling using a viscous penalty combined with a stable projection scheme*

18:00 Free time

## Time Friday (June 19)

**Emerging Methods in Modeling and Simulation – Part 2**

09:15 Hilary Weller

*Multi-fluid modelling of atmospheric convection*

*Much atmospheric convection is sub-grid-scale in climate models and so is represented by convection parameterisations. These parameterisations lead to some of the largest and most persistent errors in tropical precipitation. Convection parameterisations traditionally assume a quasi-equilibrium and that there is no net mass transport between grid columns due to convection. Therefore convection parameterisations lead to source terms in the temperature, moisture and momentum equations but not the continuity equation. If convection schemes provided source terms to the continuity equation, the model would become unstable due to explicit treatment of acoustic and gravity waves. This talk will describe multi-fluid equations to simulate sub-grid-scale convection in one fluid and stable air in another. This equation set includes interactions between convection and the continuity equation but requires changes to the whole dynamical core rather than just a stand alone parameterisation. Exchanges between the fluids are equivalent to entrainment and a new formulation for entrainment is presented. We will present solutions representing dry convection at coarse resolution and compare with high resolution solutions.*

10:00 Coffee breakout

10:20 Talk 17 – Paper 070 (Gamal, Gastaldi, Latche,Veynante)

*A second order numerical scheme for large-eddy simulation of compressible flows*

10:40 Talk 18 – Paper 064 (Natale, Todeschi)

*TPFA Finite Volume approximation of Wasserstein gradient flows*

11:00 Coffee breakout

11:30 Jan Nordbotten

*Modeling and discretization of mixed-dimensional PDEs*

*In this talk, we will discuss mixed-dimensional partial differential equations. In particular, we will extend the typical classification of such models into those of high and low dimensional gap, to models with and without degeneracy. With this backdrop, we will consider principles for modeling and discretization, and how these principles can be applied to particular geometric settings, corresponding to models appearing in applications such as flow in fractured rock or flow in biological tissue.*

12:15 Closing remarks