# Speakers

1. **Luca Alasio**
2. **Yulia Petrova**
3. **Cyril Tain**
4. **Teng Zhang**

# Abstracts

Junior Researcher Session on Multiscale Analysis and Methods for Quantum and Kinetic Problems

(15 February 2023)

## 1 Luca Alasio

*Sorbonne Université, France*

Towards a new mathematical model of the visual cycle

Abstract

The visual cycle is a fundamental bio-chemical process in the retina: it allows photoreceptors to convert light into electrical signals (phototransduction) and subsequently to return to the dark state. George Wald obtained the Nobel Prize in 1967 for his pioneering studies on this process and it has been an active field of research in Ophthalmology ever since. I will discuss the key aspects of the visual cycle in photoreceptor cells and present a new mathematical model for the visual cycle in rod cells. The model consists of a system of coupled ODEs and PDEs for the concentrations of relevant molecules and proceins in rod outer segments. The goal is to give a quantitative description of the kinetics of the main photo-sensitive molecules after exposure to light. I will explain how the model can be extended in order to account for the accumulation of toxic byproducts in the eye in connection to degenerative retinal diseases.

## 2 Yulia Petrova

*Instituto de Matemática Pura e Aplicada - IMPA, Brazil*
Two-tube model of miscible displacement: travelling waves and normal hyperbolicity

Abstract

We study the motion of miscible liquids in porous media with the speed determined by Darcy's law. The two basic examples are the displacement of viscous liquids and the motion induced by gravity. Such motion often is unstable and creates patterns called viscous fingers (or gravitational fingers). We concentrate on the important for applications property of viscous fingers - speed of their propagation. The work is inspired by the results of F. Otto and G. Menon for a simplified model, called transverse flow equilibrium (TFE). In this work a rigorous upper bound was proved using the comparison principle. At the same time numerical experiments suggest that the actual speeds are better than Otto-Menon estimates. We consider a two-tubes model - the simplest model we were able to construct which includes transverse liquid flow. For this model for the gravitational fingers we were able to find families of travelling waves and the relation between original model and TFE simplification. The main tool in the proof is normal hyperbolicity. It is work in progress with S. Tikhomirov and Ya. Efendiev.

## 3 Cyril Tain

*Université de Rouen Normandie, France*
A boundary element method for the Time Dependent Ginzburg Landau 3D model

Abstract

We solve the Time Dependent Ginzburg Landau in 3D using a boundary element method (BEM); it is implemented with the free software FreeFEM interfaced with two libraries BEMTool and HTool; boundary integral operators are evaluated via a matrix compression technique. 3D experiments in the cube and the sphere are shown : we compare the BEM method with a mixed finite element scheme using uniform boundary conditions.

# 4 Teng Zhang

*Beijing Computational Science Research Center (CSRC), China*
Numerical methods for the biharmonic nonlinear Schrödinger equation

Abstract

In this talk, I will introduce several numerical methods for the biharmonic nonlinear Schrödinger equation (BNLS) and give the corresponding error estimates, including finite difference methods and spectral time splitting methods. BNLS is frequently used in the model of nonlinear optics, since the biharmonic operator can provide extra stability for soliton solutions, which provides a model for optical fibers with strong nonlinearity. The high dispersion term from the biharmonic operator brings out numerical burdens that require either large computational domain or high accuracy method. I will discuss the error estimates and properties of Crank-Nicolson finite difference method, semi-implicit finite difference method, and sine spectral time splitting method and then compare their advantages and disadvantages. Numerical examples to illustrate the dispersion relation and simulations on soliton collisions and 2D problems are also given.