The project is inspired by recent fast development of modern technologies such as microfluidics, Lab-On-Chip, and design of innovative fluid-based materials and devices, such as micro or nano fibers, artificial and biological microswimmers, two faced 'Janus particles' or hydrogels (which are candidates for drugs-delivery systems and waste water treatment). Moreover, new modern experimental techniques allow to study motion of biological micro (and even nano) objects such as proteins, DNA, actin, microtubules, bacteria or plankton. New knowledge is gained about marine micro ecosystems, and their macroscale importance has been recently recognized.

However, theoretical understanding of basic laws of the dynamics of such nano and micro objects in fluids is still very limited. This project aims to contribute towards filling this gap. Better understanding of fundamental mechanical principles of such systems may contribute to design of novel manipulation techniques of biomaterials, such as actins or microtubuls, construction of nanoscale artificial objects and development in the environment protection.

Many of biological and artificially made nano and micro objects are elongated and elastic: semi-flexible or flexible. Characteristic patterns of their evolution under ambient flows or gravity are being studied experimentally. Amazingly, similar behavior of e.g. actin, nanofibers or chains of diatoms in shear flows have been observed. These are important findings which indicate that some of the generic features of the motion are visible also in the presence of (relatively weak) random Brownian displacements, important at nanoscales. This result supports the concept of this project to focus on dynamics of microparticles for which Brownian motion is irrelevant.

We plan to develop theoretical understanding of similarities and differences between various systems of elastic deformable objects and determine general principles of the dynamics of single or multiple flexible filaments. It is clear that this is an important task, because the above mentioned objects play important roles in Nature and technology. Diatoms, which often create elastic chains, generate most of the organic matter that serves as food for life in the sea and greatly influence global climate. On the other hand, dynamic properties of actin provide the driving force for cells to move and to divide. Nano and microfibers have a lot of innovative practical applications. Moreover, there exist many other examples of flexible elongated micro objects moving in fluids, such that their dynamics is related to important biological functions or useful for practical applications.

In this project we will study dynamics of microparticles in fluids, moving under gravity or pushed by an ambient flow. We are particularly interested in the effects of elasticity and electric charge on the dynamics. Additionally, we will investigate closely related problem of microswimmers and 'Janus particles': artificially created nano or microparticles with self-propelling properties.

One of the main topics in this project is sedimentation of microparticles. We want to investigate what is the influence of particle flexibility and electric charge. The process of sedimentation is important in industrial and environmental phenomena. In particular, dynamics of planktonic microorganisms have recently attracted attention of scientists. In our previous studies we investigated dynamics of a couple of sedimenting flexible fibres. We have found some interesting behaviors, such as mutual alignment, attraction or repulsion, dependently on the elasticity and initial configuration of the particles. Such two-particle effects are likely to have impact also on dynamics and ordering of larger groups of filaments.

In Nature, microobjects in fluids are often charged. The interesting question is how electrostatic interactions influence the microparticle dynamics in fluids. There is no stable arrangements of charges in vacuum. This was shown by British mathematician Samuel Earnshaw in 1842. And up to now, stable configurations of neutral particles settling in fluids have not been found. We have recently discovered that the story is different for charged particles in fluids. We have found stable configurations of sedimenting polydisperse charged particles in a viscous fluid. In this project we plan to study how general is this finding and what is its relevance for particulate systems in a fluid environment. We will investigate how charge influences stability of various particulate systems in fluids.

Developing theoretical description of microparticle systems, we will take advantage of the HYDROMULTIPOLE numerical code, which was developed and has been extensively used in our laboratory, in cooperation with leading scientific centers. Mathematically advanced, effective and accurate algorithm have been specifically designed for the problem of microparticle motion in fluids. We will compare theoretical results with experiments, which also will be performed within this project. We will perform video recording of different elastic and rigid particles sedimenting in a very viscous fluid (glycerin or silicon oil).