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The goal of the project is to solve some fundamental problems of contemporary high-energy astrophysics related to black holes. Astrophysical black holes can be remnants after explosions of massive stars, ending their lives, in which case the black-hole masses are between several to ~20 solar masses. The other kind are supermassive black holes, with the masses from millions to billions solar masses, found at galactic centres. Those black holes were probably formed together with the galaxies, and then increased their mass by falling of the surrounding matter due to the force of their gravity. Such a process is called accretion. During accretion, the kinetic energy of the falling matter may be released, which leads to heating and radiation. Accretion can also take place around a stellar black hole if it is a member of a binary system, and the companion star is large enough for the black-hole gravity to cause mass flow from the star onto the black hole.

The process of accretion is still not fully understood, in spite of several tens of years of studies. For surrounding matter to fall inside the black hole, its angular momentum has to be transferred outside, which process only recently has been explained by a magnetic instability. The angular momentum causes the accretion to proceed not spherically but in via a disc. Such accretion discs are often observed in cosmic sources containing black holes, and their emission is relatively well understood. On the other hand, we often observe hard X-ray radiation, which cannot come from the disc. Its origin is a subject of a current controversy. Some researchers claim that the disc almost always extends down to the innermost stable orbit around the black hole, and the source of hard X-rays is located above the black hole. Others claim that the accretion disc is truncated at a relatively large radius and replaced by a hot flow containing mildly relativistic electrons. The first goal of this project is to solve this controversy. The second goal is to measure the rotation velocities (spins) of stellar black holes through the emission of their accretion discs. This is also a controversial subject because several stellar black holes were found to have their spins close to maximal, while it is not clear how to explain it by their formation and evolution. We propose to perform new calculations taking into account the effect of energy dissipation in disc surface layers.

It turns out that not all the falling mass enters the black hole in the accretion process; a part forms bipolar outflows, jets, moving with velocities close to speed of light. The physical processes causing the jet formation are not well understood. The currently popular model explains them by outflows along the axis of a fast rotating black hole surrounded by a disc with very strong magnetic field, so strong that the magnetic pressures is equal to the ram pressure of the falling gas. This model predicts rather large jet powers. In our project, we will compare the jet powers calculated using different methods. We have so far found that the few existing methods give discrepant results. We aim at explaining these discrepancies, which will allow us to reliable test the jet formation models. The next main issue related to jets is whether jets in active galactic nuclei can emit cosmic rays and neutrinos with the highest measured energies.