The goal of this project, is to introduce the selected and promising Doctoral school student to the problem of a mass accretion on astrophysical black holes, and the related issue of a production of relativistic jets by accreting black holes, in the general context of cosmological co-evolution of supermassive black holes (SMBHs) and their host galaxies.

It is widely believed that the first black holes have formed in the early Universe due to the gravitational collapse of massive and extremely low-metallicity Population III stars. The mass spectrum of such seed black holes is a subject of an ongoing debate, with typical masses within a range from hundreds to hundreds of thousands of solar masses being discussed, depending on the particular scenario for a rapid evolution of Population III protostellar clouds and stellar objects considered. Black holes formed in this way, increased next their masses due to the accretion of a surrounding gas as well as black hole mergers, forming at the end SMBHs with masses of the order of millions of solar masses and more, which in the local Universe are associated with centres of every large galaxy. There are several unknowns regarding such an evolution, however, for example related to the relative importance of a gas accretion versus mergers in the black hole growth, or the existence of black holes with masses intermediate between seed and supermassive black holes.

Also, until now there is no clear understanding of the impact of the evolving SMBHs on their environment, although several crucial observational findings indicate the importance of a feedback between the black hole growth and the evolution of host galaxies. Namely, the matter delivered to the galactic centres during the galaxy evolution, fuels the black hole activity via accretion, and leads to the production of relativistic outflows or jets; those jets interact with the environment — in particular heating and pushing out the surrounding gas, also quenching the starformation activity — and in this way modifying the insterstellar/intergalactic medium, and so altogether regulating the accretion rate i.e. the growth and the spin evolution of SMBHs themselves.

The main goal of the project is, for the selected Doctoral school student under the supervision of the PI, to analyze possible evolutionary tracks of SMBHs in the astrophysical environment across cosmological timescales. The research is to be conducted by means of analytical studies augmented by the numerical analysis including at the latter stages of the project also advanced numerical methods, namely hydrodynamical simulations including strong gravity, relativistic bulk velocities of the plasma, and dynamically relevant magnetic fields.

Most importantly, however, the modelling of the black hole growth, the black hole spin evolution, and the feedback processes at play, is to be conducted in the direct connection to the observational data. For example, the observed level of the cosmic background radiation in the X-ray domain, which is believed to be dominated by the radiative output of accretion disks surrounding SMBHs during their quasar activity phase, is known to constrain the black hole spin distribution. At the same time, relativistic jets produced in active galactic nuclei are most likely the dominant source of the cosmic background radiation in the radio and gamma-rays ranges. The emerging constraints can be used in a meaningful way in developing and testing various scenarios for the growth and spin evolution of SMBHs, when augmented by detailed population studies of active galaxies of various types. The novelty of the approach in the research project proposed here, is to add in this context also the constraints imposed by the observed multi-wavelength time variability of relativistic jets in active galaxies.