Approximately 84% of the mass in the Universe exists in the form of dark matter, whose origin continues to remain one of the greatest and most challenging problems in modern astronomy. One of the possible explanations for that scientific riddle postulates that dark matter may be composed of primordial black holes that formed in the early Universe.

Unlike stellar-mass black holes, which are the products of the evolution of massive stars, primordial black holes can, in principle, have a broad range of masses – from tiny, asteroid-mass black holes, to giant behemoths, thousands of times more massive than the Sun. Astronomical observations carried out in the past decades did not find evidence for primordial black holes more massive than the Moon and ruled them out as a dominant component of dark matter. Similarly, the least massive black holes, less massive than a trillion kilograms, would emit detectable Hawking radiation if they composed a large fraction of dark matter.

The previous observations and experiments were not sensitive to asteroid-mass primordial black holes, which can still make up a significant fraction of dark matter. If true, asteroid-mass primordial black holes would inevitably collide with Galactic neutron stars, creating low-mass black holes that cannot be explained by standard stellar evolution. However, identification of isolated neutron stars and black holes, let alone low-mass black holes, remains nearly impossible, restricting the known neutron stars and black holes almost entirely to binary star systems only (and it is still unknown whether such a sample is even representative of the entire population).

To solve those problems, motivated by imminent breakthroughs in the interferometric and astrometric observations of gravitational microlensing events, I propose to develop a novel method that will not only allow discoveries and characterization of isolated compact objects, but will make them routine. In result, using astrometric and interferometric observations of microlensing events, I will create the first-ever catalog of masses of several isolated neutron stars and black holes.

I will observe gravitational microlensing events with the GRAVITY instrument using a technique called interferometry. GRAVITY combines the light from four 8-m Very Large Telescopes, rendering it possible to resolve objects located extremely close to each other in the sky. Astrometric observations involve precise measurements of the positions of stars in the sky using the European Space Agency’s Gaia satellite. I will combine interferometric and astrometric observations of microlensing events with the photometric observations collected by the OGLE survey, an experiment carried out by Polish astronomers using a 1.3-m telescope located in Chile. This will allow me to precisely measure masses, distances, and transverse velocities of isolated objects, including isolated neutron stars and black holes.

These observations will enable me to answer several fundamental and pressing questions regarding - How massive stars die? - What the mass function of isolated stellar remnants is? and - If black holes are born with natal kicks? A big data set collected in the proposed project will also provide an ultimate test of the black hole dark matter hypothesis. If confirmed, together with the detection of low-mass black holes, this would be a breakthrough that would profoundly change our understanding of the Universe. Negative results would still be of great value, as they would put to rest all existing theories of black hole dark matter.