Accretion onto Exotic Compact Objects and Their Observational Signatures

As per the predictions by Einstein's theory of gravitation, general relativity(GR), black holes are objects unlike any other known to us in the universe. Each black hole is surrounded by an imaginary quasi-spherical boundary called the event horizon. When surrounding material falls into the black hole, it is compressed and heated to extremely high temperatures, but it can no longer be detected once it passes through this boundary, as the incredible gravitational pull of black hole prevents anything from escaping from the event horizon. This leads to the formation of a "silhouette" of a black hole: a dark shape on a bright background of light coming from the surrounding matter, deformed by a strong gravity. This is often referred to as the "shadow" of a black hole. Outside the horizon light may orbit the black hole several times before escaping towards the distant observer, in fact, at a certain distance form the horizon light may travel around a circle, this leads to the formation of bright observable rings of a distinct shape and size. Observing images of such rings, and these allow the mass and other properties of the black hole to be determined, based on.Einstein's general theory of relativity. However there are alternative theories of gravity that predict a slightly different shadow geometry. Hence detecting the shadow of a black hole can be a quantitative test of general relativity.

Over the past few years, we have witnessed the popular images black hole in the center of the galaxy M87 and in the center of our own galaxy Sgr A*, taken by the Event Horizon Telescope (EHT) collaboration. EHT collects light from the black hole using a number of telescopes which are spread all over earth. This can give us information about the structure of black hole. However, due to the limited number of telescopes, it has only partial information about the structure of black hole. The reconstruction of the images corresponding to the observed EHT data is not unique. EHT uses a complicated image reconstruction algorithm to obtain the most probable image from the observed data.

Our project is mainly focused on performing numerical simulations around black hole. These simulations work by solving on a grid (of discrete points in space) equations of motion of matter in strong gravity. increasing the number of grid-points the simulation improves the accuracy of the solution. Taking into account all of the important physics, general relativity, magnetohydrodynamics requires immense computational power. Using supercomputers with hundreds or even thousands of processors ("cores") we will be able to obtain very accurate solutions in a reasonable time. These simulations will play a key role in predicting what the EHT might see for different types of compact objects (black holes, naked singularities etc.). We aim to simulate the environment close to black hole event horizon and to construct synthetic images from these simulations. These synthetic images can be directly compared with the observed EHT images. The library of image templates currently used by the EHT only contains Kerr black holes. We are going to add more templates to this library by simulating other exotic objects from alternative theories of gravity such as naked singularities. This will be essential to understand whether the observed EHT images are indeed a black holes or something else. Our synthetic image library can be useful for future EHT observations.