Description for the general public (in English)

There are many interesting and exotic objects in our fascinating universe. Over the past centuries, many new discoveries have been made unlocking the several mysteries of the Universe. Among these discoveries, the black holes are the least known objects since they do not emit any detectable radiation by themselves. This is because of the fact that the matter density and gravity is infinitely large, not allowing even the light to escape. Until now, astrophysicists agree with the existence of two classes of black holes depending on their mass. Black holes that are few to tens of massive than Sun are called stellar mass black holes which are believed to be born when an extremely massive star at its late stage of evolution, explodes as a supernova. On the other hand, there exists a supermassive black hole (SMBH) at the centre of galaxies, and has mass millions to billions times the Sun. This system is called the active galactic nuclei (AGN) and is the most luminous and persistent source of electromagnetic radiation in the universe. It is well established fact that the AGN are powered by the accretion of surrounding mass onto the SMBH at the center. During the process of accretion, the amount of energy released per second is very high i.e., several billions times the energy released by Sun. While most of the material is accreted onto the SMBH via accretion disk, significant portion of it flows away from the nucleus in the form of outflows and jets. The emitted radiation, before reaching to the observer, interacts with the hot and ionised material present in the line of sight. Despite the significant researches done in the past decades, there exists several unanswered questions regarding this system. What causes the material to flow away from the vicinity of SMBH despite its tremendous force of gravitational attraction? Where does the outflow originates and how it is connected with the process of accretion? How does the outflow affects the various components of the host galaxy? What are the physical conditions of the material present in the ouflow and what is its chemical composition? How does the chemical composition in the outflow correlates with heavy element abundance in the universe? In this project, we plan to address some of these questions, if not all, by utilizing the data obtained from observations and performing the computer simulations.

Since the matter is subjected to the intense radiation emitted from the central source of AGN, almost all the elements present are partially or completely ionised. The radiation matter interaction causes the transition of electrons between various energy levels of the atoms and produces numerous absorption lines with energies corresponding to the energy of excited ions. Since the material is hot, the energy centroid of the absorption lines corresponds to extreme UV and mostly X-rays. The absorbing material is called the warm absorber. These lines are seen in the spectra obtained by the spectrometers installed in the satellites on board in space. For the detection of X-ray lines, space satellites are required since Earth's atmosphere absorbs the X-rays coming from the distant sources, and therefore cannot be detected with the ground based instruments. We aim to investigate the observed absorption lines and compare it with the results obtained from the computer simulations. The simulations takes into account all the atomic process and solves all the concerned mathematical equations providing us with the detailed thermal and ionization structure of the cloud. The spectra containing the absorption lines that an observer would detect can also be obtained from these simulations. The simulations will be iterated until the results are closest to the one obtained from the observations. Comparison of observed spectra with the simulated one will allow us to constrain the various parameters of the absorber: temperature, density, column density, pressure, degree of ionisation, chemical abundances etc.

This project will have a great impact in the understanding of how the material from the close vicinity of the SMBH affects the various processes happening in the host galaxy. Knowing the physical conditions of the plasma subjected to the intense radiation is extremely important as it happens in many different astrophysical environments, most prominently in the close vicinity of the SMBHs. In general, our result will be very promising and useful for further research of AGN feedback processes and its possible connection with the accretion disk via which most of the material is injected into the monster black hole. More specifically, we plan to study the abundance of heavy metals in the outflow, in particular the abundance of Iron. Since the material is subject to intense radiation, there exists all levels of ionised species of the various atoms. The strength of absorption for several sources, measured in terms of absorption measure distribution (AMD), will be computed by using the ionization and thermal structures obtained from the output of simulations. The AMDs computed from the simulations will then be compared with the observationally derived AMDs and the best fitted models will be found. This analysis will potentially provide the insight into the distribution of the matter at different distances from the central SMBH as well as for the estimation of heavy elements distribution in the Universe.

The results from the observational data of current X-ray satellites such as *XMM-Newton* and *CHANDRA* have motivated the astronomers to investigate the unknown issues regarding the AGN outflow. There has been significnat researches done with exciting results in the recent years, both from the observational and theoretical analysis, though lots of questions still remain unanswered. European Space Agency has already approved the next generation of X-ray satellite *ATHENA* to be launched in 2028, which is expected to come up with a lots of new and fascinating discoveries. Particularly, the X-ray spectrometer *X-IFU* (X-ray integral field unit) of *ATHENA* will have 10 times better spectral resolution than any other currently working X-ray satellites and will detect all the absorption lines due to highly ionised heavy elements with unprecedented accuracy. Using the transmitted spectra obtained from our models, we shall be able to predict the high resolution spectra with many absorption lines that *X-IFU* can detect. The result our project will certainly be useful in designing the instruments of *ATHENA*, in which Poland is also involved for the construction of some mechanical accessories of *X-IFU* detector.