Popular summary of the project

Weather effects in using disk continuum time delays in active galactic nuclei to measure the expansion rate of the Universe

Active galactic nuclei in general, and their bright tail – quasars – are extremely bright sources populating the entire Universe up to high redshifts. **Thus quasars are potentially perfect probes to determine the expansion rate of the Universe.**

And such probes are urgently needed. The measurements of the Hubble constant performed with the use of different methods give confusing results. Most measurement using small/intermediate redshift objects like Supernovae Ia imply in general higher values of the expansion rate than measurements of the properties of the cosmic microwave background, corresponding to the redshift 1000, when transformed to the current stage of the Universe. If the standard model describes the Universe expansion well over all epochs, then these two measurements should agree. The disagreement in turn may imply a need for the new physics. However, measurements are difficult, and their systematic errors are difficult to assess. So we plan to use active galaxies as complementary probes.

The emission generated very close to the black hole is strongly variable, and this variable illumination of the accretion disk surrounding the central black hole creates a light-echo effect. The time delay of this echo, according to the theory, is directly related to the absolute (monochromatic) luminosity of the source. Thus measuring this time delay, and the observed flux, we can calculate from this theory the distance (more precisely, the luminosity distance) to the source. Measuring additionally the redshift of the active galaxy, we can locate each of the measured sources on the Hubble diagram and measure the expansion rate, including the Hubble constant.

The problem is that the observed echo from the disk seems to be heavily contaminated by the second light echo, from the medium at some distance from the disk, most probably clouds which are the source also of strong and broad emission lines. In this project, we propose a **four-step methodology** how to decompose the observed signal into the disk signal and the signal from the second reprocessor. The wavelength-dependent response is different for these two reprocessors, since the disk emits locally approximately as a black body while the second reprocessor is clearly a partially ionized, most likely a clumpy medium imprinting spectral features like emission lines and pseudo-continua. We will model the response of both media theoretically, in detail, and we will prepare a software which combines the two responses into a single signal ready to be compared to the data. **As the first step,** we will just include two timescales while during the **second step,** we will incorporate the specific wavelength-dependent shape of the reprocessor discussed above. In order to model better the second clumpy medium, we will use theoretical predictions of how this material can flow out of the accretion disk. One such prediction (**step no. three**) will be based on our own model of the cloud dynamics under the radiation pressure acting on dust. Another branch of predictions (**step no. four**) will come from modeling other processes which also operate in an active nucleus, specifically a cloud disruption due to the black hole tidal forces, cloud-cloud collisions, cloud passages through the disk, and stellar collisions with the accretion disk. These two steps will allow us to create a response which includes spatial 3-D geometry.

Finally, the code containing two light echo options will be used to model the photometric data from the **Vera C. Rubin Observatory** which will perform the Legacy Survey of Space and Time (**LSST**) starting from 2023. In mid-2024, the first season data that we need for the project should be available, and we will use the active galaxies located in the Deep Drilling Fields where about 3000 sources should be found. We will determine the value of the Hubble constant and we will evaluate its accuracy through extensive simulations.