Acceleration of UHECR by local supermassive black hole candidates

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Executive summary

The origin and acceleration mechanism of ultra-high-energy cosmic rays (UHECR) with energy exceeding the GZK-cutoff limit remain unknown. It is often speculated that supermassive black holes (SMBHs) located at the centers of many galaxies can serve as possible sources of UHECR. This is also supported by recent observations of high-energy neutrinos from blazar, as neutrinos are the tracers of UHECR. In this contribution, we explore the capabilities of nearby SMBHs (located within 100 Mpc distance) to accelerate UHECR of certain energy and composition by the novel, ultra-efficient regime of the magnetic Penrose process, in which protons and ions are energized near SMBH by the ionization or decay of low-energy neutral particles, such as e.g. a hydrogen ionization or neutron beta-decay.

We have selected 25 nearby SMBH candidates with known masses, spins and magnetic fields. Calculating the mean proton energy resulting from the acceleration process, we presented results in a table. Applying the model to SMBH located at the center of our Galaxy, we found that Sgr A* can serve as a PeVatron accelerating protons up to the energies coinciding with the knee of the cosmic ray spectrum. One can also note that the mean proton energy averaged over all selected extragalactic sources appears to be around 10^{19} eV. Existence of many sources at such energies can be potentially relevant in the interpretation of the ankle of the cosmic ray spectra, though, expected cosmic ray spectrum from particular objects are yet to be determined.

Extreme conditions around SMBHs increase chances for engagement of the accelerated UHECR in the production of the cosmic ray ensembles (CRE), i.e. a group of correlated two or more cosmic ray particles, including photons with the same parent particle or a common primary interaction vertex. We discuss the unique signatures of UHECR and CRE produced around SMBHs, potentially observable with a global network of detectors, as proposed by the Cosmic-Ray Extremely Distributed Observatory – CREDO.