Contribution ID: **74** Contribution code: **EGAL** Type: **Poster**

High-energy neutrino emission from global accretion flows and outflows around supermassive black holes: a GRMHD simulation-based model

Monday 2 September 2024 09:43 (1 minute)

The spectral energy distributions (SEDs) of the high energy neutrino emitted from the accretion flows are still highly uncertain, because the global structure of the accretion flow can affect the neutrino SEDs. We have calculated very high energy neutrino SEDs by using three-dimensional general relativistic magnetohydrodynamic (GRMHD) simulations data of a magnetized accretion flow around a spinning black hole. We solve the trajectories of the tracer-particles of nonthermal protons along the field lines of GRMHD snapshots. The SEDs of the nonthermal protons are calculated by solving the Fokker-Planck equation in the rest frame of the tracer-particles. We assume the effects of the turbulent accelerations with the hard-sphere approximation and compression/expansion of the fluid elements. For the hadronic processes, we consider the effects of the pp collisions and subsequent high energy neutrino emissions taking into account the effect of the gravitational redshift.

We set a supermassive black hole with 100 million solar mass and the dimensionless spin parameter 0.9375. We have found that the neutrino SED become flatter than the previous 1 zone models because of the superposition of the neutrino SED emerged from the different position of the accretion flows. This is the effect of the global structure of the accretion flows. The nonthermal protons emitting neutrinos can be classified to the three types: (i) Inflowing protons eventually trapped by the black hole, (ii) outflowing protons quickly escape towards an observer, (iii) initially inflowing protons which finally become outflowing protons and escape towards an observer. We have found that the protons of the type (iii) reside in the turbulent accretion flows in longer time than the ones of type (i), so that the emission from nonthermal protons eventually escape as outflows dominates the resulting neutrino SED.

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Session Classification: Poster hang