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Constraining the baryon loading factor of AGN jets: implication from the gamma-ray emission of the Coma cluster

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High-energy cosmic rays (CRs) can be accelerated in the relativistic jets of Active Galactic Nuclei (AGNs) powered by supermassive black holes.
The baryon loading efficiency onto relativistic CR baryons from the accreting black holes is poorly constrained by observations so far. In this presentation, we suggest that the γ-ray emission of galaxy clusters can be used to study the baryon loading factor of AGN jets, since CRs injected by AGN jets are completely confined in the galaxy clusters and sufficiently interact with intra-cluster medium via hadronic process, producing diffuse γ-rays.
We study the propagation of CRs in the galaxy clusters and calculate the radial distribution of the gamma-rays in the galaxy cluster with different injection rates from AGNs.
By comparison with the γ-ray flux and upper limits of the Coma cluster measured by $Fermi$-LAT and VERITAS, we find the upper limit of the average baryon loading factor (defined as the efficiency with which the gravitational energy is converted into relativistic particles) to be $\eta_p < 0.1$.
The upper limit is much lower than that required to account for diffuse neutrino flux in the conventional blazar models.

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Summary

Galaxy clusters can effectively confine the CRs in cosmological times, so CRs can sufficiently interact with ICM to produce γ-ray and neutrino radiation.
In our study, taking into account effects of the injection history of AGN jets, we have studied the propagation and distribution of CRs in the Coma cluster and obtained constraints on the average baryon loading factor using the γ-ray observations.
The upper limits of the average baryon loading factor are $\eta_p \sim 0.01$ and $\eta_p \sim 0.1$, respectively, from the $Fermi$-LAT and VERITAS observations for various cosmic-ray power-law indexes.
We also use the integral radiation energy to obtain the upper limits on the conventional baryon loading factor $\eta_{p,\mathrm{rad}}$, which are $\eta_{p,\mathrm{rad}} \sim 1$ ($Fermi$-LAT) and $\eta_{p,\mathrm{rad}} \sim 10$ (VERITAS), respectively. If such a constraint can be generalized to all the AGN in the universe, one may conclude that blazars cannot be the major sources of the diffuse neutrino background measured by IceCube, when comparing this upper limit to the theoretically required one.

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