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Microquasar jet-cocoon systems as PeVatrons and the origin of cosmic rays

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The origin of Galactic cosmic rays (CRs), particularly around the knee region (∼3 PeV), remains a major unsolved question. Recent observations by LHAAASO suggest that the knee is shaped mainly by protons, with a transition to heavier elements at higher energies.
Microquasars – compact jet-emitting sources – have emerged as possible PeV CR accelerators, especially after detections of ultrahigh-energy gamma rays from these systems. We propose that the observed proton spectrum (hard below a few PeV, steep beyond) arises from the reacceleration of sub-TeV Galactic CRs via shear acceleration in large-scale microquasar jet-cocoon structures.
Our model also naturally explains the observed spectrum of energies around a few tens of PeV by summing up heavier nuclei contributions. Additionally, similar reacceleration processes in radio galaxies can contribute to ultrahigh-energy CRs, bridging Galactic and extragalactic origins. Combined with low-energy CRs from supernova remnants and galaxy clusters around the second knee region, this scenario could provide a unified explanation for CRs across the entire energy spectrum.

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