Calculations predict surprising quark diffusion in hot nuclear matter

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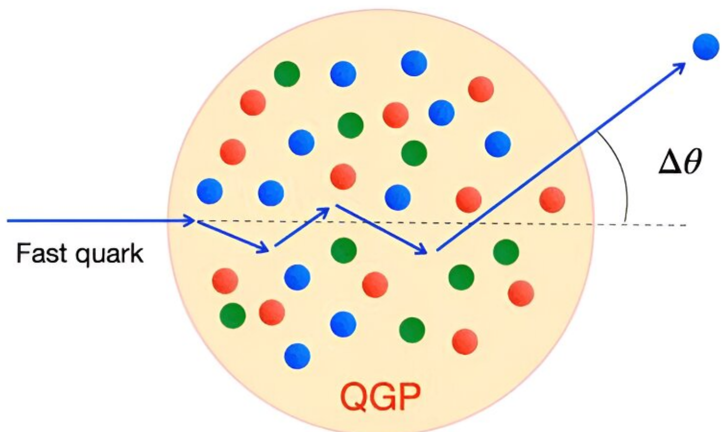

When an energetic quark travels through a "soup" of "free" quarks and gluons—the quark-gluon plasma (QGP)—non-local quantum effects should cause it to scatter faster and at wider angles than expected from mere local interactions. Credit: Brookhaven National Laboratory

Scientists can use powerful colliders to smash atomic nuclei together to create a quark-gluon plasma (QGP). This "soup" of quarks and gluons, some of the fundamental building blocks of matter, filled the early universe. Tracking how high energy jets of quarks travel through the QGP can reveal information about the QGP's properties.

Scientists' simplest assumption is that local interactions with the quarks and gluons will deflect these energetic particles. But recent theoretical calculations that also include non-local quantum interactions—those interactions beyond a particle's immediate surroundings—predict a super-diffusive process. This means that the complex interactions in QGP deflect quarks faster and at wider angles than can be explained by local interactions alone.

Early calculations based on the theory of strong interactions suggested that jets would undergo a diffusive process caused by random deflections as the energetic particles interacted with the quarks and gluons that make up the plasma—similar to the way pollen particles on the surface of a pond get "kicked" around by water molecules.

Counter to these early calculations, nuclear theorists at Brookhaven National Laboratory recently discovered that including non-local quantum effects—which arise from long-lived gluon fluctuations—predicts significant deviations from the expected diffusion pattern in QGP. Including these non-local effects predicts that energetic jets will undergo a super-diffusive process, broadening the angle of the jet faster than local interactions alone can explain.

Their research has been published in the *Journal of High Energy Physics* and *Physical Review D*.

The predictions can be tested by tracking energetic jets in the QGP created in high-energy heavy ion collisions at the Relativistic Heavy Ion Collider (a Department of Energy user facility at Brookhaven National Laboratory) and the Large Hadron Collider in Europe.

More information: Paul Caucal et al, Universality aspects of quantum corrections to transverse momentum broadening in QCD media, *Journal of High Energy Physics* (2022). DOI: 10.1007/JHEP09(2022)023

Paul Caucal et al, Anomalous diffusion in QCD matter, *Physical Review D* (2022). DOI: 10.1103/PhysRevD.106.L051501

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