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The Color Glass Condensate: Big picture questions, interdisciplinary connections and some recent developments

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At very high energies, the multitude of gluons and sea quark fields that fundamentally make up the structure of hadrons, organize themselves on very short time and distance scales, as a form of strongly correlated matter called the Color Glass Condensate (CGC). Though intrinsically quantum in nature, it behaves as a classical lump and many of its features can be explored using semi-classical methods in quantum field theory. Remarkably, key features may be universal and share properties with systems across energy scales, ranging from Black Holes to ultracold atomic gases. The CGC can be probed cleanly at the Electron-Ion Collider, which will commence operations at decade's end; we will briefly address its discovery potential and related theory challenges.

The CGC framework also provides a first principles understanding of the Glasma matter formed in the thermalization process towards the formation of a Quark-Gluon plasma (QGP) in ultrarelativistic heavy-ion collisions. We will outline some of the striking phenomena in the Glasma, in particular the discovery of turbulent nonthermal fixed and universal features they share with cold atomic gases. We will end these lectures with a discussion of the possible role of the CGC in spin diffusion within polarized protons at high energies. This can be understood as a fascinating interplay between the topology of the QCD vacuum represented by instanton-anti-instanton tunneling between vacua and over-the-barrier sphaleron-like transitions induced by CGC fields.

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