Color Memory

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Based on:
1707.08016/hep-th with Raclariu and Strominger
1805.12224/hep-ph with Ball, Raclariu, Strominger and Venugopalan
Background

Gravitational Memory

The Infrared Triangle

Zel’dovich & Polnarev, 1974

Strominger & Zhiboedov, 1411.5745
Strominger, 1703.05448
The Color Memory Effect

A permanent relative color rotation of a pair of “test” quarks induced by the transit of color flux across null infinity.

\[ u_i < u < u_f: \]
- color radiation flux through \( I^+ \)
- gauge choice \( A_u = 0 \)
  \[ \Rightarrow \text{no color evolution} \]
  \[ (\partial_u q = iA_u q = 0) \]

\[ u < u_i: \]
- color singlet
- flat connection on \( CS^2 \)
  \[ A = iU dU^{-1} = 0, \]
  \[ (U = 1). \]
A permanent relative color rotation of a pair of “test” quarks induced by the transit of color flux across null infinity.

\[ u > u_f: \]

- no radiation \( \Rightarrow \) flat connection
  \[ A = iU dU^{-1} \]
- classical constraint
  \[ -\partial_u D^a A_a = J_u + \partial_u F_{ru} \]
  \[ \Rightarrow A \neq 0 \ (U \neq 1) \]
- quarks acquire relative color rotation
  \[ U(z_1)U^{-1}(z_2) = \mathcal{P} \exp \left( i \int_{z_2}^{z_1} A \bigg|_{u_f} \right) \]
  \[ \Rightarrow \text{“memory” of color flux} \]
Measuring Color Memory

- DIS of electrons off heavy ions
- Regge limit $\rightarrow$ classical YM sourced by hard partons
  (McLerran, Venugopalan, and many more)
- “test” quarks $\rightarrow$ quark dipole $(q\bar{q})$
- color flux $\rightarrow$ hard partons in ion
- dipole cross-section
  $\sim$ color singlet survival probability

\[ \sigma_{\text{dipole}} \sim 1 - \langle \text{Tr} \left( U(z_1)U(z_2)^{-1} \right) \rangle_{\text{color source ave.}} \]

- inclusive DIS virtual photon-heavy ion cross-section

\[ \sigma_{\gamma^*\text{ion}} \sim \int_{z_1, z_2} |\psi_{\gamma^*\rightarrow q\bar{q}}|^2 \sigma_{\text{dipole}} \]
The memory effect in classical Yang-Mills theory is the permanent relative color rotation of a pair of “test” quarks induced by the transit of color flux across null infinity.

Measurement of a color memory effect may be experimentally accessible in the Regge limit of deeply inelastic scattering processes at electron-ion colliders.