Intertwined chiral restoration and polarization dynamics

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Introduction

- Recent Discovery of spin polarization of Λ-hyperons introduces a new observable in heavy-ion collision experiments.
- Equilibrated spin degrees of freedom explain (with $\omega \to \varpi$) the global spin polarization but fails to explain the longitudinal spin polarization.
- We examine the role played by the equation of state to the polarization of the system.

Formalism

- Lagrangian: $\mathcal{L} = i\,\bar{\psi}\partial\!\!\!/\psi + G\left[\left(\bar{\psi}\psi\right)^2 + \left(\bar{\psi}i\gamma_5\psi\right)^2\right]$, Equation of motion: $\left[i\,\partial\!\!\!/ - \sigma(x) - i\gamma_5\,\pi(x)\right]\psi = 0$; $\sigma \equiv -2G\left\langle\bar{\psi}\psi\right\rangle$, $\pi \equiv -2G\left\langle\bar{\psi}i\gamma_5\psi\right\rangle$
- Wigner Function: $\mathcal{W}_{\alpha\beta}(x,k) \equiv \int d^4y\, e^{ik\cdot y}\, G_{\alpha\beta}\left(x+\frac{y}{2}, x-\frac{y}{2}\right)$, where, $G_{\alpha\beta}(x,y) = \left\langle\bar{\psi}_\beta(y)\psi_\alpha(x)\right\rangle$.
- Kinetic Equation: $\left[\left(k^\mu + \frac{i\hbar}{2}\partial^\mu\right)\gamma_\mu + \frac{i\hbar}{2}\left(\partial_\mu\sigma\right)\partial^\mu_{(k)} - i\gamma_5\pi - \frac{\hbar}{2}\gamma_5\left(\partial_\mu\pi\right)\partial^\mu_{(k)}\right]\mathcal{W}(x,k) = 0.$
- Clifford Decomposition: $\mathcal{W} = \mathcal{F} + i\gamma_5\mathcal{P} + \gamma_\mu\mathcal{V}^\mu + \gamma^\mu\gamma_5\mathcal{A}_\mu + \frac{1}{2}\sigma^{\mu\nu}\mathcal{S}_{\mu\nu}.$
- Kinetic Equation for Axial part under semi-classical expansion: $k^\alpha\left(\partial_\alpha\mathcal{A}^\mu\right) + M\left(\partial_\alpha M\right)\left(\partial^\alpha_{(k)}\mathcal{A}^\mu\right) + \left(\partial_\alpha \ln M\right)\left(k^\mu\mathcal{A}^\alpha - k^\alpha\mathcal{A}^\mu\right) = 0.$
- Canonical Spin Tensor: $S^{\lambda\mu\nu}_{\rm can}(x) = \frac{1}{2}\,\varepsilon^{\lambda\mu\nu\alpha}\int d^4k\,\mathcal{A}_\alpha(x,k)$ Relation to GLW Spin Tensor: $S^{\lambda\mu\nu}_{\rm can} = S^{\lambda,\mu\nu} + S^{\mu,\nu\lambda} + S^{\nu,\lambda\mu}.$
- Equation for Canonical Spin Tensor: $\partial_\alpha S^{\alpha,\gamma\delta} = \left(\partial_\alpha \ln M\right)\left(S^{\gamma,\delta\alpha} - S^{\delta,\gamma\alpha}\right) \neq 0.$

Analytical Solutions

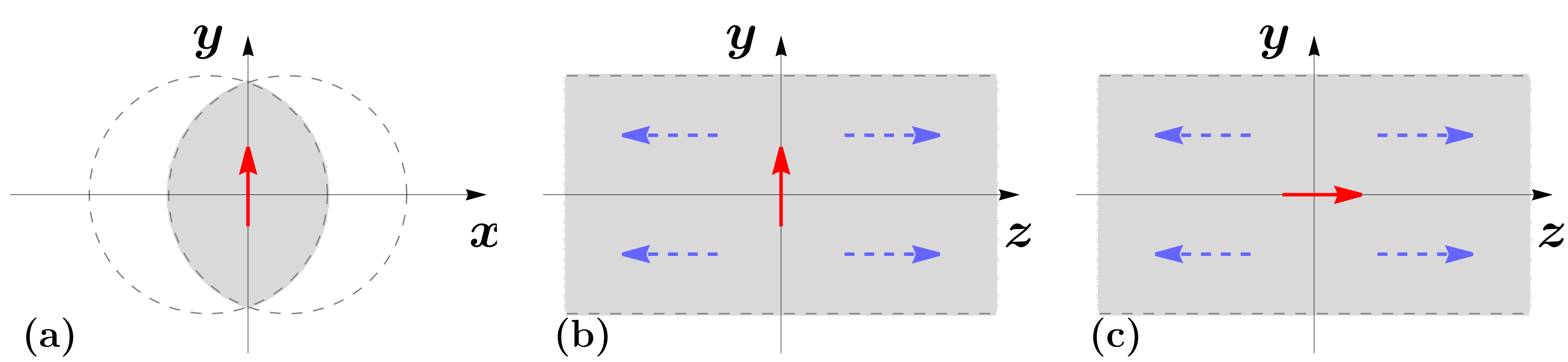

Figure 1: (a): Longitudinal view of non-central collision; (b): Transverse polarization; (c): Longitudinal polarization.

- Parameterizing, $S^{\lambda,\mu\nu}$ by a scalar, $\sigma(\tau)$, under boost-invariance we find a solution in (b) and (c): $\sigma(\tau)\,\tau = \sigma(\tau_0)\,\tau_0 \to M(x)$ is decoupled from spin.
- By breaking boost-invariance, we find the solution: $\sigma\,(t,z) = M_0\,\sigma_0\,(z - \nu\,(t - t_0))\,/M(t).$

Conclusions

1. Gradients of effective mass can act like a source of spin polarization.
2. Spin evolution decouples from the source term in a highly symmetric system.
2. By giving up boost-invariance, we find a connection between spin polarization and chiral restoration.

Outlook

1. The system may be considered to be rotating.
2. Consequences of non-zero π should be explored.
3. Self-consistently solved $M(x)$ should be used.

References

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SQM2024