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# The Polyakov loop and the Hadron Resonance Gas Model

E. Megías[1], E. Ruiz Arriola[2], L.L. Salcedo[2]

[1] *Grup de Física Teòrica and IFAE, Departament de Física, Universidad Autònoma de Barcelona, Bellaterra E-08193 Barcelona, Spain*
[2] *Departamento de Física Atómica, Molecular y Nuclear and Instituto Carlos I de Física Teórica y Computacional, Universidad de Granada, E-18071 Granada, Spain*

Contact email: *emegias@ifae.es*

The Polyakov loop has been used repeatedly as an order parameter in the deconfinement phase transition. We describe results [1] for the confinement-deconfinement phase transition as predicted by the Nambu–Jona-Lasinio model where the local and quantum Polyakov loop is coupled to the constituent quarks in a minimal way (PNJL). We observe that the leading correlation of two Polyakov loops describes the chiral transition accurately [2]. On the other hand, using quite general chiral quark models of QCD featuring spontaneous chiral symmetry breaking and implementing the quantum and local nature of the Polyakov loop [1,3], we argue that, in the confined phase, its expectation value can be represented in terms of hadrons, similarly to the hadron resonance gas model for the pressure [4,5,6]. Specifically,

$$L(T) \approx \frac{1}{2} \sum_{\alpha} g_{\alpha} e^{-\Delta_{\alpha}/T},$$

where $g_\alpha$ are the degeneracies and $\Delta_\alpha$ are the masses of hadrons with exactly one heavy quark (the mass of the heavy quark itself being subtracted). We show that this approximate sum rule gives a fair description of available lattice data with $N_f$ = 2+1 for temperatures in the range $150\,\mathrm{MeV} < T < 190\,\mathrm{MeV}$ with conventional meson and baryon states from two different models. For temperatures below $150\,\mathrm{MeV}$ very recent lattice results [7,8] can be described only if exotic hadrons are present in the QCD spectrum

This work opens the possibility of a Polyakov loop spectroscopy, i.e. using the Polyakov loop in fundamental and higher representations to deduce multiquark states, gluelumps, etc, containing one or several heavy quark states.

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