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The heavy quark-antiquark potential from lattice and perturbative QCD

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The heavy quark-antiquark potential in perturbative QCD is subject to ambiguities. We show how to derive a well-defined and stable short-distance potential that can be matched to results from lattice QCD simulations at intermediate distances. The static potential as well as the order 1/m potential are discussed.

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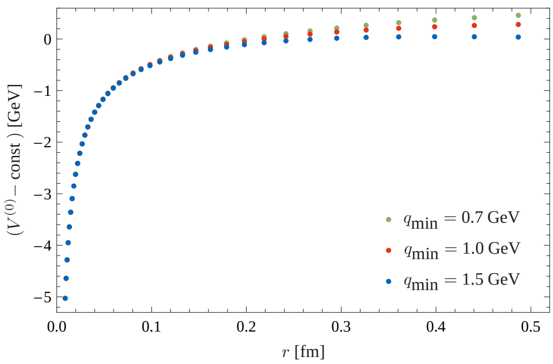
The static quarkonium potential has been studied by lattice simulations as well as in perturbative QCD. It is an ideal object for exploring the interplay between perturbative and non-perturbative physics. However, the perturbative prediction tends to fail already at very small distances. It was found that this behaviour can be understood in the context of renormalons [1].

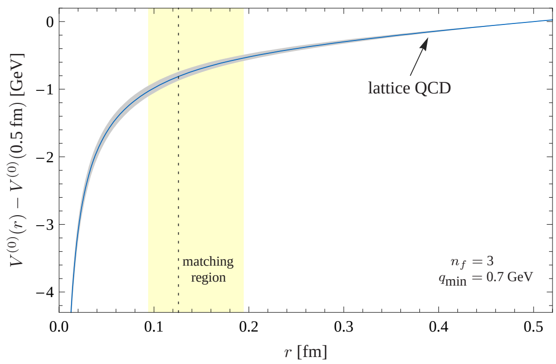
At two-loop order the static potential reads in momentum space [2]

$$\tilde{V}^{(0)}(|\vec{q}|) = -\frac{4\pi C_F \alpha_s(|\vec{q}|)}{\vec{q}^{\,2}} \left\{ 1 + \frac{\alpha_s(|\vec{q}|)}{4\pi} a_1 + \left(\frac{\alpha_s(|\vec{q}|)}{4\pi} \right)^2 a_2 + \dots \right\},$$

where $\vec{q}$ is the three-momentum transfer. Higher order terms involving IR divergences are not considered at this point. We define the static potential in coordinate space by a restricted Fourier transform with a low-momentum cutoff q_{min}:

$$V^{(0)}(|\vec{r}|) = \int\limits_{|\vec{q}|>q_{\mathrm{min}}} \frac{d^3q}{(2\pi)^3}\, e^{i\vec{q}\cdot\vec{r}}\, \tilde{V}^{(0)}(|\vec{q}|).$$





In contrast to the usual approach, the running coupling α_s is not expanded in a power series, but full four-loop RGE dependence in included in the transformation to coordinate space. The resulting potential depends only weakly on the cutoff (left figure) and can be matched at distances r between 0.1 and 0.2 fm to a potential obtained from lattice QCD [3]. The error band of the curve in the right figure reflects uncertainties in the Sommer scale $r_0 = 0.50 \pm 0.03$ fm (lattice part) and uncertainties in the scale dependence of $\alpha_s(|\vec{q}|)$ (perturbative part). The order 1/m potential can be defined analogously and can also be matched well to calculations from lattice QCD [4].

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References

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