LA-UR- 00 - 4404

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Title: Spectroscopy 'Windows' of Quark-Antiquark
Mesons and Glueballs with Effective Regge
Trajectories

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Submitted to: Confinement IV, 4th International Conf. on
"Quark Confinement and the Hadron Spectrum"
July 3-8, 2000, Vienna, Austria

Los Alamos

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**Spectroscopy "windows" of quark-antiquark mesons and glueballs
with effective Regge trajectories.**

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Regge trajectories of quark-antiquark mesons can be well approximated for phenomenology purposes by a specific nonlinear form, reflecting that the flux tubes cannot be arbitrarily large, but breaks due to the effect of pair-production. If confirmed, this would imply that there is only a finite number of bound states on each trajectory, and consequently, an existence of "spectroscopy windows" for each flavor. Here we present our results for these windows.

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It is a paradigm in QCD that Regge trajectories (roughly speaking, functions that relate angular momentum of a state to its mass squared) of mesons are linear. This picture arises in the Veneziano model for the amplitudes, string theory of hadrons and also, at least asymptotically, from potential models with a linear confining potential.

On the other hand, Regge trajectories extracted from data are *nonlinear*. In addition to being disfavored by experiments, linear trajectories also lead to problems in theory. (For details on both experimental and theoretical aspects, and references, see ¹.)

All the theoretical concepts that lead to linear Regge trajectories in QCD overlook one feature of QCD - the production of color singlet pairs. Pair production is only virtual at short distances, but as the energy of the flux tube increases, it is possible (and likely) to create a real pair and the breaking of the flux tube is energetically favorable. One can argue that hadronic Regge trajectories cannot rise indefinitely, and they acquire a curvature due to pair production which screens the confining QCD potential at large distances ². Once the nonlinearity of Regge trajectories is an accepted fact, the question of what specific form should be used for phenomenology arises.

We have considered a whole class of nonlinear trajectories allowed by dual amplitudes with Mandelstam analyticity (DAMA) (³ and references therein).

DAMA allow for Regge trajectories of a form

$$\alpha_{ji}(t) = \alpha_{ji}(0) + \gamma [T_{ji}^\nu - (T_{ji} - t)^\nu] \quad (1)$$

where ν is a constant restricted to $0 \leq \nu \leq \frac{1}{2}$; γ is a universal constant; T_{ji} is a trajectory threshold, $\alpha_{ji}(0)$ is its intercept, and i, j refer to flavor. For any $\nu \neq 0$ in this interval, the trajectory becomes purely imaginary at the trajectory threshold (in other words, its real part terminates); for $\nu = 0$ it develops a constant imaginary part. This means that any $\nu \neq 0$ trajectory supports only a finite number of bound states, with their value of angular momentum limited by $\alpha(T)$. Beyond the threshold, there are continuum states. This picture seems to have captured the essence of the effect of pair production.

The largest deviations of the true trajectory from any of these forms can be expected for the states near the threshold. The sensitivity of the parameters on the specific form (i.e. value of ν) is also interesting. We found that the least sensitive is the threshold (up to few percent), and the most sensitive is the resultant maximum angular momentum¹. This means, in our opinion, that the values of thresholds extracted from data can be taken seriously, regardless of what form is assumed. We have argued that both limiting cases ($\nu = 1/2$ and $\nu = 0$) can be expected to work comparably well for lowest lying states (and thus, any ν in between), but the $\nu = 1/2$, so-called square-root, form is likely to be more realistic. Therefore, we use the square-root form for phenomenological purposes.

Assuming that Regge trajectories are of the form (1) with $\nu = 1/2$, we determine thresholds and intercepts of trajectories by using various experimental information. Typically, we use masses of a few known lowest lying states, and in the case of the ρ trajectory we also use the value of the intercept (which is known and well-established) found from exchange processes. The value of γ (the universal asymptotic slope) is fit to the ρ trajectory, and then taken as universal for all other trajectories.

The approach has more predictive power than one would naively expect. The number of parameters for any two parity related 5-flavor multiplets^a (i.e. 20 trajectories in all) is only 12, in contrast to 40.

I would like to concentrate here on just one of the numerous consequences and implications. Specifically, if we are right, there exist "spectroscopy windows" as shown in Figure 2. This may simplify identification of states observed in experiments, and might be beneficial in search for exotics.

^a An example of a pair of parity partners trajectories is the ρ and a_2 trajectories; the 5-flavor multiplet containing the ρ trajectory includes K^* , ϕ , D^* , D_s^* , J/ψ , B^* , B_s^* , B_c^* and Υ trajectories.

Figure 1: Mass windows for quark-antiquark states of listed flavor, together with known masses of states belonging to the vector-, tensor, pseudoscalar- and axial-vector- trajectories. n refers to light quarks. For example, the nn tower contains $I = 1$ mesons π , ρ , a_1 , a_2 etc.

Acknowledgments

This research is supported in part by the U.S.D.O.E. under contract W-7405-ENG-36, and grant DE-FG02-97ER-41029.

References

1. M.M. Brisudova, L. Burakovsky, T. Goldman, *Phys. Rev. D* **61**, 054013 (2000).
2. M.M. Brisudova, L. Burakovsky, T. Goldman, *Phys. Lett. B* **460**, 1 (1999).
3. L.L. Jenkovszky, *Riv. Nuovo Cim.* **10**, 1 (1987).