Analysis Of Pure Experimental Hadronic Regge Trajectories

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Introduction

We have analyzed the spectrum of hadrons by the latest data available through the Particle Data Group[1], with the aim of pinpointing trajectories with which hadronic resonances can be associated. It was recognized that the entire range of Regge trajectories (RTs) for hadrons are not straight and parallel lines. Out of total 66 plotted trajectories, 64.81% are essentially non-linear, 27.78% are essentially linear, while 7.41% are fairly linear. We have extracted a number of inherent parameters of these RTs such as slopes, variance, string tension among quarks and have deduced results which are both in coherence as well as in sharp contrast to the conventional ones. Existence of 15 new resonance particles has been predicted along with some of their intrinsic parameters. The flavour dependence of RTs is also interrogated.

2. Analysis Of Experimental Hadronic Data

The entire data of the spectrum of bound states of light quarks is well described by essentially linear(EL), fairly linear(FL) as well as essentially non-linear(EN) RTs[2] both in the (N_R,M^2) and in the (J,M^2) plane(Chew Frautshi plots), where M is the mass of a state, J is its spin, and N_R is the radial quantum number. We have attempted to express M^2 as a function of J, since the angular momentum does not have experimental uncertainties. Also, expressing M^2 as a function of N_R is beneficiary as N_R is also free from discrepancies. This illustrates the reliability of the linear parameterisation in the form:

$$M^2=\alpha J+C_1 \quad \text{and} \quad M^2=\alpha' N_R +C_2$$

The most appropriate parameters which describe the essential deviations of RTs from linearity and parallelism are variance and the average value of slope$\langle\alpha\rangle$ for a particular given RT. For the case of essentially linear RTs, we evaluated their slopes and also calculated the string tension among the constituent quarks. Both these parameters exhibit essential deviations from the standard universal values (1.1GeV^{2}for slope and 0.145GeV^{-2} for string tension). A universal value of slope is plausible only if the strings joining the quarks have constant string tension $\alpha=1/(2\pi\sigma)$ (where σ is the string tension).The variance V~ 0 indicates that there is no deviation from the standard value for slope. Some of the RTs(doublets) are too short to judge non-linearity because of scarcity of data, but the values for their slope and string tensions prove out to be beneficiary.

3. Mesonic Sector

We have constructed all possible orbital and radial RTs for this sector. Out of the plotted 35 mesonic RTs, 66.67% are EN while 26.67% are EL and 6.67% are FL. The light unflavoured (u-d sector) mesonic particles and resonances appear first on the list. Lately, this sector has been enriched with a large number of new entries. There are a total of 11 EL and FL RTs in this regime, and the slope value ranges between 0.697-1.227 GeV^{2}and the calculated range of string tension spans between 0.697-1.227 GeV^{-2}. A common pattern which is reflected here is a consistent decrease in slope with increasing quark mass for a particular set of RTs.

In the strange meson sector, the analysis of the K-meson spectra gives rise to nine RTs, out of which four are radial and the rest being orbital.

Although, our entire analysis spans over a mass spectra range below 2,500 MeV, but the radial RTs covered for charm (J/ψ(1^{--})) and the bottom sector (γ(1^{--})) witness the inclusion of higher mass scales (up to 11020MeV). The γ(1^{--}) radial RT is 6-plet and EN with a very high mean slope value of 6.388 GeV^2 and variance 11.055 GeV^2. The J/ψ(1^{--}) radial RT is a 5-plet and is EN with $<\alpha>$ =1.478 GeV^2 and variance =0.681 GeV^2.

By analyzing EL and FL RTs, we have predicted the existence of 7 new resonance particles in the mesonic sector along with their spin and parity.

1) $f_2(1735)$ $J^{PC}=2^{++}$ 2) $\omega_3(2000)$ $J^{PC}=3^{--}$
3) $a_0(1070)$ $J^{PC}=0^{++}$ 4) $\varphi_3(1770)$ $J^{PC}=3^{--}$
5) $\varphi_5(2290)$ $J^{PC}=5^{--}$ 6) K(1325) $J^P=0^-$
7) K(2265) $J^P=3^+$

4. Baryonic Sector

In the baryonic sector, a total of 31 RTs have been plotted, out of which 62.5% are EN, while 29.17% are EL and 8.33% are FL. Under the non-strange sector, the nucleon spectra gives rise to the major orbital trajectory $P_{11}(1440)$-$D_{13}(1700)$-$F_{15}(2000)$-$I_{1,11}(2600)$ which is EL with slope = 0.945GeV^2 and the string tension being 0.168 GeV^{-2}. The $D_{15}(1675)$-$F_{17}(1990)$-$G_{19}(2250)$-$I_{1,11}(2700)$ orbital RT is also EL and its slope and string tension matches the standard universal value. Three radial RTs have been plotted in the N-sector and all turn out to be triplets and are EN. In the Δ sector, the major P_{33} orbital RT $P_{33}(1232)$-$F_{37}(1950)$-$H_{3,11}(2420)$-$I_{3,13}(2750)$-$K_{3,15}(2950)$ is FL with slope = 1.196 GeV^2 and string tension= 0.133 GeV^{-2}. The $P_{33}(1600)$-$F_{35}(1905)$-$G_{37}(2200)$-$G_{39}(2400)$ orbital RT is EL and has slope almost equal to the standard value. The available data helped in plotting two radial RTs in the Δ sector. Both are EN and triplets with the average values of slopes lying close together.

In the strange sector, we shall only discuss the Σ-Λ spectra because the data available for the Ξ hadron spectroscopy is not sufficient for any analysis. Λ orbital RT $S_{01}(1670)$-$P_{03}(1890)$-$F_{05}(2110)$ having slope = 0.831 GeV^2 and string tension= 0.192 GeV^{-2}is EL. The second EL major orbital RT is $D_{03}(1520)$-$F_{05}(1820)$-$G_{07}(2100)$-$H_{09}(2350)$ with slope= 1.073 GeV^2 and string tension=0.1483 GeV^{-2}. One Λ orbital RT comes out to be EN. In the Σ sector, four orbital RTs were plotted and three turned out to be EL, while one is FL.

An analysis for EL and FL RTs, we have predicted the existence of 7 new resonance particles in the baryonic sector along with their spin and isospin.

1) $\Delta(2180)$ J=2.5,I=1.5 2) $\Delta(1145)$ J=0.5,I=1.5
3) N(1250) J=1.5,I=0.5 4) N(2215) J=3.5,I=0.5
5) N(2415) J=4.5,I=0.5 6) N(2485) J=5.5,I=0.5
7) $\Lambda(1050)$ J=0.5,I=0 8) $\Sigma(1385)$ J=0.5, I=1

5. Flavour dependence of RTs

We have tried to investigate the feature of flavour depedence of RTs on the experimental front. This is done by plotting the parent (N_R=0) and daughter RTs (N_R=1,2) for the different flavour contents and calculating the average value of slopes for them. Due to scarcity of experimental data, we were unable to plot daughter RTs for the charm and the bottom sector. Table1 clearly depicts a decrease in average value of slopes as the quark mass increases with flavour. It is interesting to note that the average values of slopes are almost independent of N_R both for the u-d and s family. Our results clearly match with the theoretical values calculated by other physicists [3] under the non-relativistic quark model.

Table 1:- Average value of slopes in GeV^2 for mesonic trajectories with N_R=0,1,2

N_R	Up-down	Strange	Charm	Bottom
0	1.0814	1.2595	0.43	0.34
1	0.787	1.763		
2	0.8395			

Furthermore, analysis of the plotted FL and EL orbital RTs reveals that the values of slopes decrease consistently as we approach the RTs with higher mass flavours. Correspondingly, the string tension among quarks increases with decreasing slope. Thus, as the masses of the constituent quarks comprising the hadrons increases, there is an increase in the energy per unit length among these quarks.

References

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[3] A. Inopin and G.S.Sharov, Phys.Rev. **D63**, 054023 (2001).