Application of the Oscillation Symmetry to various theoretical hadronic masses

Boris Tatischeff

Université Paris-Saclay, CNRS/IN2P3, IJCLab, Orsay Cedex, France

Abstract

Several theoretical results of meson and baryon masses are compared to experimental data using the Oscillation Symmetry method. This method allows to compare the calculated masses to the experimantal ones, whereas these last are clearly less numerous.

1. Introduction

In the same way as opposite kinetic and potential forces produce oscillations in classical physics, they produce also oscillations in masses (and widths and also in several other properties) in quantum physics. So oscillations have been observed [1] in hadrons [2], [3], fundamental and excited state nuclei [4], astrophysical bodies [5], and physical properties of various Hydrocarbons [6]. They also have been observed in E1 and M1 electromagnetic transitions [7]. In particle physics, the masses result through kinetic and potential interactions. In the astrophysical physics, the forces are gravitational and centrifugal, related to their kinetic energies. The common property of almost all bodies is that they are composed of smaller bodies.

When an unique variable of a given system is studied, the data are first classified in increasing order. The possible oscillations are studied using the following relation:

$$m_{(n+1)} - m_n = f[(m_{(n+1)} + m_n)/2] \tag{1}$$

where n indicates the increasing data order. The differences between two successive data are plotted versus their corresponding mean val-

Email address: `boris.tati@orange.fr` (Boris Tatischeff)

ues. The data of such studies, corresponding to relation (1), are named "property data" where here property may be either mass or width. The study of one variable versus another one is performed by the variation of the first versus the second one.

A simple normalized cosine function is used for the fits of the data. For "mass data" studies, M is the variable $(m_{(n+1)} + m_n)/2$ and Δ M is the function .

When all studied data are positive their oscillations are fitted using the following formula:

$$\Delta M = \alpha(1 + cos(M/M_1))exp(\beta.M) \tag{2}$$

where M/M_1 are defined within 2π. The oscillation period P = 2 πM_1.

α, β, and M_1 are the three fitted parameters. There values are given in Table A1.

Below, several experimental hadronic "mass data" are fitted using the formula described above. Then several theoretical hadronic "mass data" are compared to the experimental fits so as to make a judgment on the agreement between the corresponding model and the experimental data, while there are not always corresponding experimental values.

2. Mesons

2.1. Isoscalar scalar mesons

Fig. 1(a) shows the "mass data" of the new values of the isoscalar scalar meson [8], fitted with the period P=279.6 MeV. Old values of f_0 "mass data" [9], with large uncertainties, have been analyzed previously with oscillation symmetry [3] and fitted with a larger period P=377 MeV.

Fig. 1(b) shows the new values of the widths versus masses of the isoscalar scalar mesons [8], fitted with the period P=274.9 MeV. The corresponding old data were also fitted with a larger period P=358.1 MeV. The periods describing the isoscalar scalar meson widths and "mass data" are close. The fit between oscillations and data are very good, both obtained with close neighboring periods.

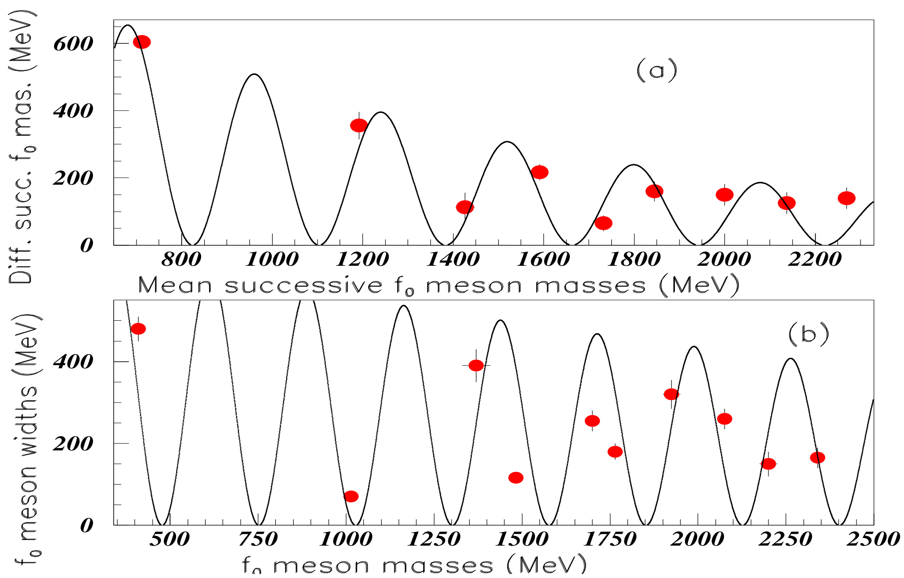

Figure 1: Color on line. (See text). Inserts (a) and (b) show respectively the "mass data" then widths versus masses of the new values of the isoscalar scalar mesons.

2.2. Strange mesons

The new strange meson masses and widths are read in [9] and [10]. Their "mass data" are presented in fig.2 separated in two mass ranges since there is no value in [10] between M=2000 MeV and M=4000 MeV:

- the "mass data" of the first range 1400$\leq$ M$\leq$2000 MeV are shown in fig. 2(a) and fitted with the period P=417.8 MeV.

- Insert (c) shows the total width of the same data plotted versus the corresponding masses, and fitted with period P=245 MeV.

- the "mass data" of the second range 4000$\leq$ M$\leq$4700 MeV are shown in fig. 2(b) and fitted with the period P=515.2 MeV.

-Insert (d) shows the total width of the second range data, plotted versus the corresponding masses, and fitted with period P=232.5 MeV.

In both ranges, the width periods are smaller than the mass periods. The previous values of strange mesons [9] have been analyzed previously with oscillation symmetry [3] in a restricted range ($\leq$200 MeV) and separated by their spin J (0, 1, and 2). The new fits (and some data) are different from previous.

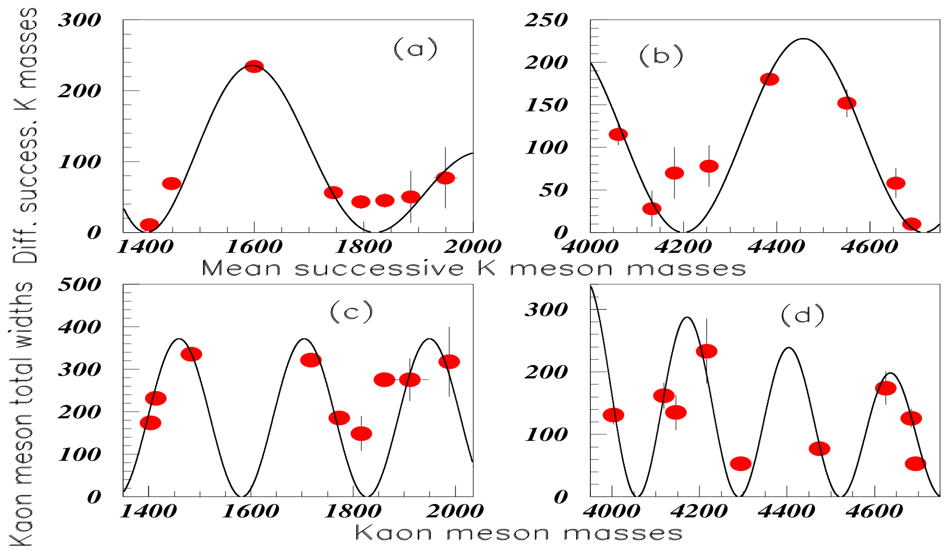

Figure 2: Color on line. (See text). Inserts (a), (b), (c), and (d) show respectively the "mass data" of both new strange meson ranges, then widths over masses of the same meson ranges.

2.3. Mesons with Charm

2.3.1. Charmed mesons

New experimental and theoretical values of Charmed mesons are read in [8]. Fig. 3 shows, using full red circles, the corresponding experimental "mass data" fitted with period P=94.6 MeV. The other marks show the following theoretical results :

-full blue squares corrrespond to the original GI model updated by Godfrey and Moats [11],

- full green upside triangles correpond to the QCD motivated relativistic quark model (R. Q. M.) [12], and

- purple full downside triangles correspond to the modified GI model taking into account the screening effect (GI-Screen) [13].

A rather good agreement is observed between measurements and calculations, although it is not easy to observe the predictions of one calculation to be clearly better than the results of other calculations. Many predicted charmed meson masses are not expêrimentally observed.

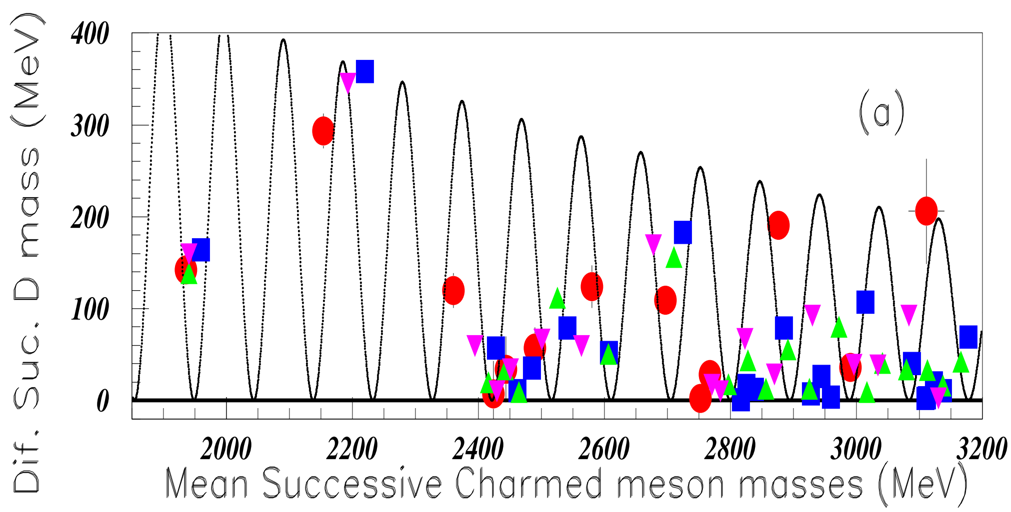

Figure 3: Color on line. (See text). Red full circles show the new experimental Charmed mesons "mass data". The other marks show several predicted theoretical "mass data".

2.3.2. Charmed strange mesons

Fig. 4 shows new "mass data" values of Charmed Strange mesons [8]. Experimental "mass data" are shown with black stars, and fitted with P=147.5 MeV. The other marks correspond to theoretical "mass data":

- full red circles show the "mass data" obtained using the original GI model updated by Godfrey and Moats [11].

- full blue squares show the "mass data" obtained using the QCD motivated relativistic quark model (R.Q.M.) [12],

- full green upside triangles obtained with the modified GI model taking into account the screening effect (GI-Screen) [14].

Many masses are theoretically predicted but not observed. The agreement with experiment is a little better for GI-Original, than for the other models.

2.3.3. Charmoniums

The "mass data" of the exotic charmonium-like resonances in the mass region (3900-4700) MeV, analyzed in the relativistic strong coupling theory [14], are reported by blue full squares in fig. 5. They are compared to corresponding experimental "mass data" [9] drawn by full red circles. A few theoretical results are located outside the

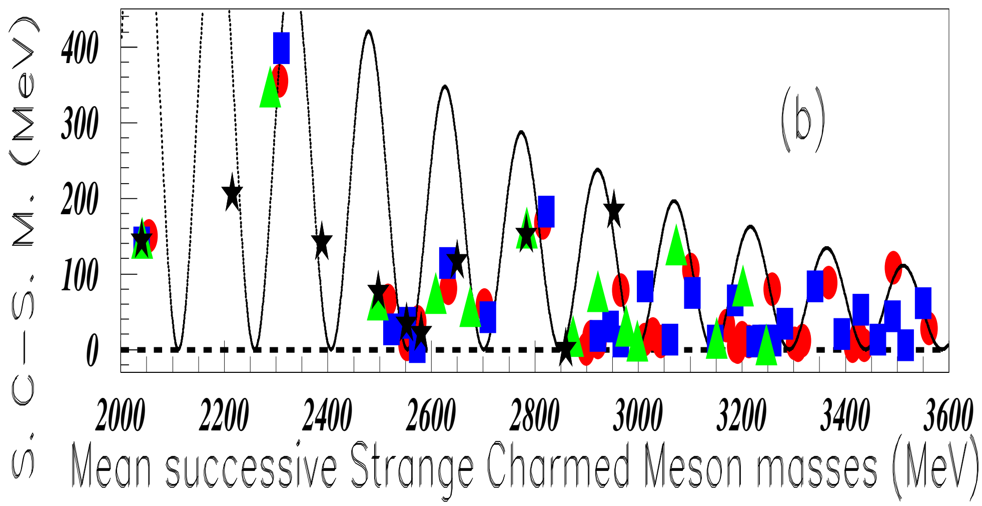

Figure 4: Color on line.(See text). Charmed-strange mesons "mass data".

experimental fit.

2.4. Bottom and Bottom Strange Mesons

The "mass data" of the Bottom (Beauty) mesons are shown in fig. 6(a) and strange Bottom mesons in fig. 6(b). They are obtained using the new values in [8]. A shift close to 80 MeV is observed between bottom and bottom strange mesons.

The experimental "mass data" are shown by black full stars. The full circled red marks correspond to the GI model updated by Godfrey, Moats, and Swanson (GI-Orginal) [24], the full blue squares to the motivated relativistic quark model (R.Q.M.), and the full upsided green marks to the modified GI-Screen model. In insert (a), starting at "mass data" 6400 MeV the oscillations of the fits obtained using lower "mass data" describe very well the R. Q. M. theoretical results, but not as well the GI-Original theoretical results. The same is observed for the Strange meson "mass data" for masses larger than 6480 MeV.

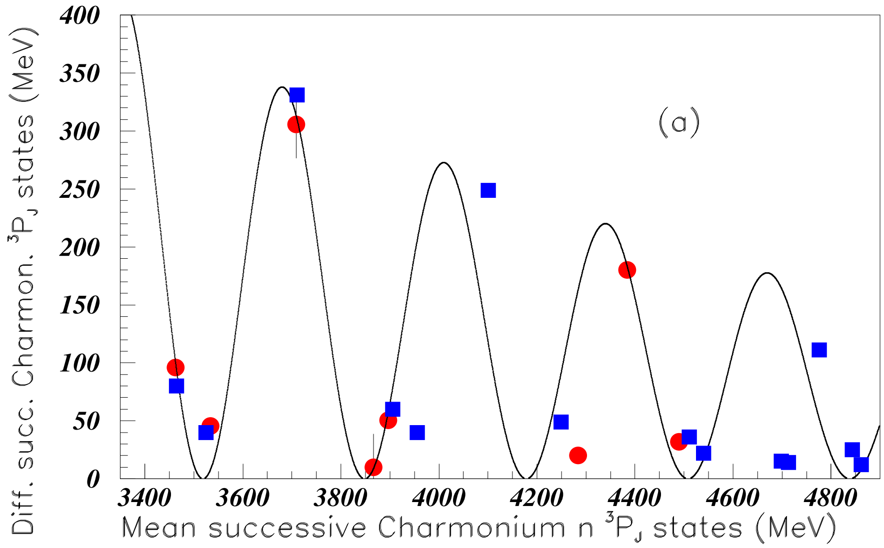

Figure 5: Color on line.(See text). Charmonium ^3P_J mesons "mass data".essai 430

3. Baryons

3.1. Charmed Baryons

Λ_C, Ξ_C, and Ω_C calculated baryon "mass data" [8] are compared to experimental results in fig. 7. Σ_C data are omitted in this study since only three such experimental masses are known.

Experimental values of the Charmed "mass data" baryons are presented in fig.7 by full black stars [9]. Theoretical corresponding results obtained from various quark models [8] are shown: full red marks correspond to RQM (relativistic quark model) [15], full blue squares correspond NQM model [16], full green upside triangles correspond to modified NQM model [17] and full purple down side triangles correspond to another modified quark model [18].

Insert (a) shows the "mass data" of the Charmed Λ_C baryon masses, fitted with P=116.2 MeV. The result of the NQM model is less good than observed by the other calculations.

Insert (b) shows the "mass data" of the Charmed Ξ_C baryon masses, fitted with P=115.3 MeV. The result of the modified NQM model [17] is again less good than observed by the other calculations.

Insert (c) shows the "mass data" of the Charmed Ω_C baryon masses, fitted with P=116.2 MeV. Here the results of the NQM model [16] are

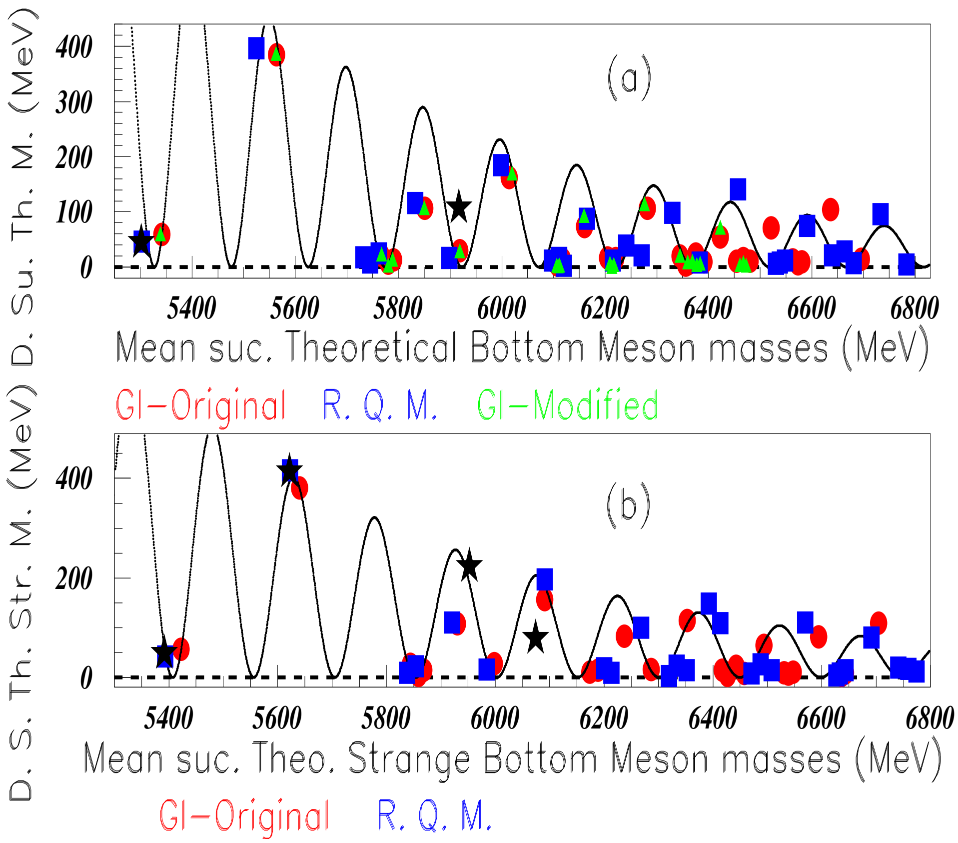

Figure 6: Color on line. Bottom and bottom-strange mesons "mass data".(See text).

less good as those obtained by the other calculations.

These three periods are nearly the same. The Ξ_C "mass data" found with the RQM [15] and NQM [18] models disagree from measured data at the "mass data" close to 2710 MeV. Several NQM [17] "mass data" are also outside the fit obtained with experimental values.

3.2. Bottom (Beauty) Baryons

As in previous figs., the experimental "mass data" of the Λ_B bottom (beauty) baryons are shown in fig. 8(a) by full black stars. They are fitted with the period P=267 MeV. The RQM [8] [15] theoretical "mass data" are shown by full red circles, the NQM [8] [16] "mass data" are shown by full blue squares, and the NQM [8] [17] "mass data" are shown by full upside green triangles. The RQM [16] results reproduce well the Λ_B and Ω_B experimental baryon masses.

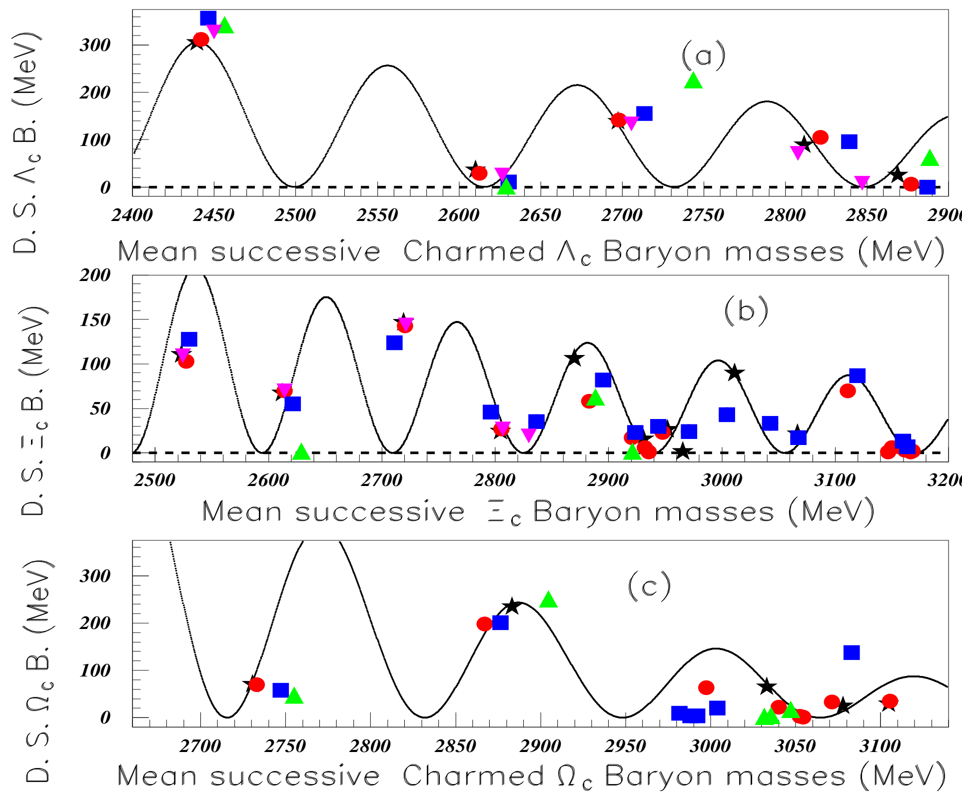

Figure 7: Color on line. Inserts (a), (b), and (c) show several calculated "mass data" compared to experimental results of Λ_C, Ξ_C, and Ω_C baryons.

The masses of the Ξ_B "mass data" shown in fig.8(b) are exactly obtained for the four first RQM "mass data" but are not correctly reproduced for masses larger than 6227 MeV. The NQM Ω_B values shown in fig.8(c) are better found with the model used in [16] than with the model used with [17]. No theoretical values are given in [17] for Ξ_B.

4. Discussion and Conclusion

The oscillation symmetry allows to discuss the agreement of the theoretical hadronic masses with the rather small number of experimental ones. Indeed the fits of the "data masses" exhibit a simple analytical shape.

The oscillation periods are meaningful, contrary to the other two parameters: α and β which depend on the mass value at the beginning

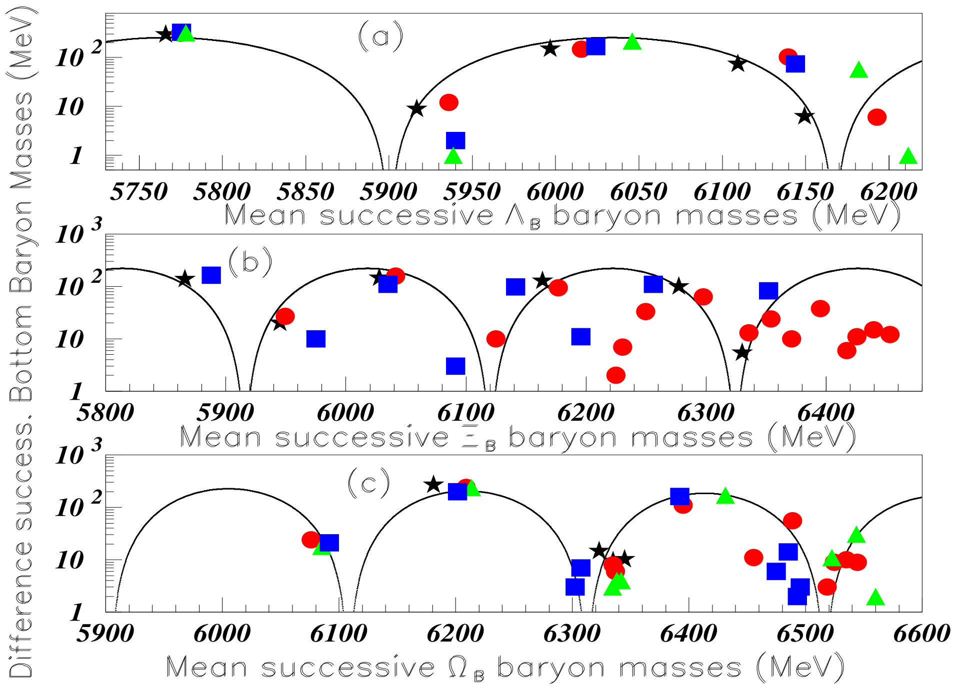

Figure 8: Color on line. Inserts (a), (b), and (c) show several calculated "mass data" compared to experimental results successively of Λ_B, Ξ_B, Ω_B baryon masses. (See text).

of the study.

Previous papers highlight several similarities between the obtained "data" corresponding to different studied bodys. It was shown previously in [21] that the same distribution can describe the "mass data" variations of several different "data". For exemple, it was shown in [22] a figure showing a common fit for several Gas exoplanet "mass data", or in [2] a figure pointing out a common distribution for several hadronic familly periods plotted versus the lowest mass of the corresponding hadronic famillies.

The same property was shown in [21] inside a fig. reproduced here (fig. 9), where the following marks show the "mass data" of:
- f2 mesons (full blue squares),
- f0 mesons (full green stars),
- Ξ baryons (full red circles) with an homothetic factor, that is to say that all masses of this familly are multiply by the same factor hf=0.94,
- Ξ_C baryons, (full upside purple triangles) with an homothetic factor

Table A1: Parameters of the fits

Fig.	α(MeV)	β(MeV^{-1})	P(MeV)
1(a)	605	-0.0009	279.6
1(b)	359	-0.00025	274.9
2(a)	1950	-0.00175	417.8
2(b)	114	0	515.2
2(c)	186	0	245
2(d)	4050	-0.0008	232.5
3	780	-0.00066	94.6
4	5150	-0.00129	147.5
5	1850	-0.00065	329.7
6(a)	$9.9*10^5$	-0.00151	148.9
6(b)	$9.9*10^5$	-0.00142	148.9
7(a)	6100	-0.00151	116.2
7(b)	4800	-0.00151	115.3
7(c)	$4.03*10^7$	-0.0044	116.2
8(a)	126	0	267.0
8(b)	110	0	204.2
8(c)	2150	-0.00049	204.2

hf=0.91,
- ^{14}N excited state levels (black empty stars inside empty squares) with an homothetic factor hf=114.

It was also shown that the differences between periods obtained using "mass data" and widths of several bodys, exhibit a constant value rather than a variable shift. Such result was pointed out in previous papers like [23], inside which the reported shifts are 64 MeV for mesons and for 23 MeV for baryons. The same variation between periods is observed here.

The periods extracted from the present paper are drawn in fig.10. The horizontal dashed lines are obtained using the relation P=80+19*x MeV. We observe a like "quantification effect", the shift here being equal to $\approx$ 19 MeV. This value is obtained for the study of common meson and baryon periods, therefore in reasonable agreement with the values quoted previously for separated hadrons.

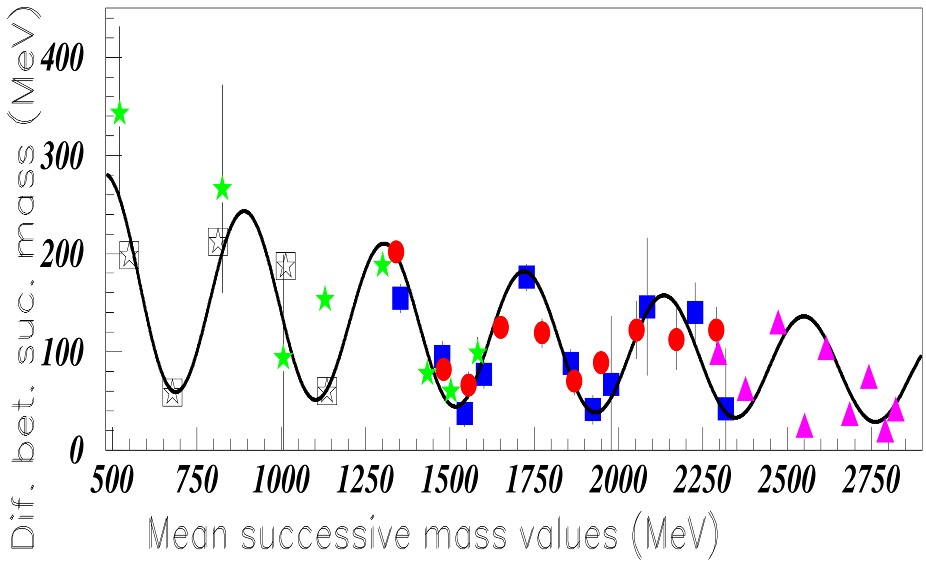

Figure 9:

In conclusion, the paper brings out new data of the oscillation symmetry, confirming its generalization property.

The main result is again to observe the existence of a new relation between different masses.

The existence of a simple fit in "mass data" allows to compare different theoretical calculated masses to measured values.

These results confirm the previous observations that oscillations are widely observed inside many properties in nature.

These results deserve theretical studies, clearly outside the scope of the predent work.

References

[1] B. Tatischeff, "Oscillation symmetry applied to: 1) hadronic and nuclei masses and widths, 2) astrophysics. And used to predict unknown data.", Proceedings of the 15^{th} International Conference on Nuclear Reaction Mechanisms, Varenna (Italy).

[2] B. Tatischeff, "Connections between hadronic masses in the one hand and between fundamental particle masses in the other

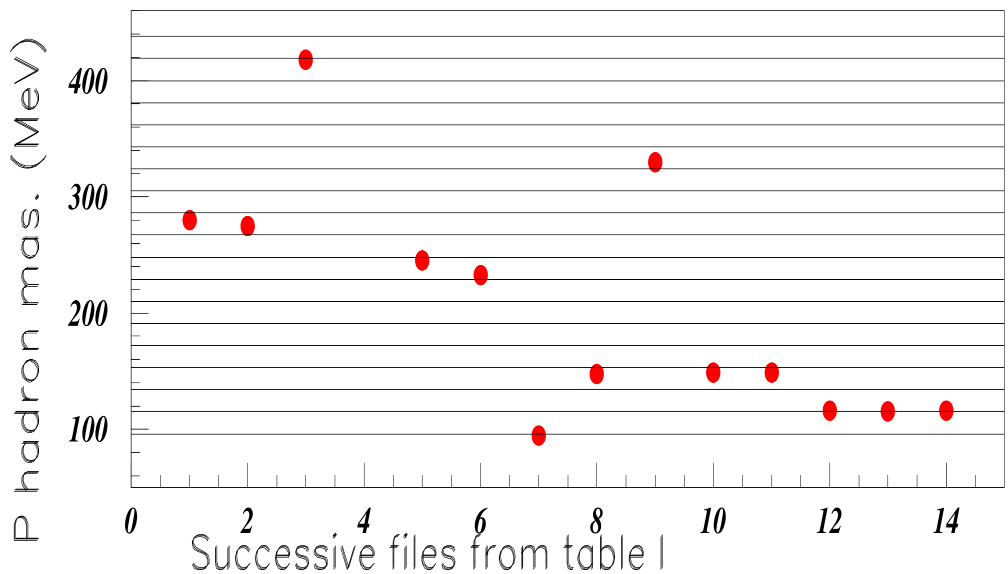

Figure 10: Color on line. See text. Periods (in MeV) extracted previously, versus successive figures. essai428

hand", Journal of Advances in Applied Mathematics, JAAM V.5, N.3, http://www.isaac-scientific.org.

[3] B. Tatischeff, "Hidden properties of meson and baryon masses and widths", https:// vixra.org/abs/2201.0004.

[4] B. Tatischeff, "Observation of oscillation symmetry in nuclei excited state masses and widths", vixra.org/abs/2111.0010v1.

[5] B. Tatischeff, "Oscillation symmetry applied to some astrophysical masses, and allowing to highlight remarkable relations between masses", Physics and Astronomy International Journal PAIJ-04-00206-2.pdf. DOI:10.1506/paij.2020.04.00206.

[6] B. Tatischeff, "Test of Oscillation Symmetry applied to some physical properties of various Hydrocarbons", https://vixra.org, 2206.00898v1.pdf DOI:10.1506/

[7] B. Tatischeff, "Application of the Oscillation Symmetry to the Electromagnetic Interactions of Some Particles, Nuclei, and

Atoms", Journal of Advances in Applied Mathematics, Vol. 6, N. 2, 2021. doi.org/10.22606/jaam.2021.62003.

[8] Hua-Xing Chen, Wei Chen, Yan-Rui Liu, and Shi-Lin Zhu, "An updated review of the new hadron states", arXiv:2204.02649v1 [hep-ph] 6 Apr 2022.

[9] Particle Data Particle Data Group, P. A. Zyla et al., Review of particle physics, Prog. Phys. 6 (2020) 083C01.

[10] R. Aaij *et al.* LHCb collaboration, "Observation of new resonances decaying to $J/\Psi K^+$ and $J/\Psi\Phi$", Phys Rev. Lett. 127 (2021) 082001, arXiv:2103.01803 [hep-ex].

[11] S. Godfrey, K. Moats, Properties of excited charm and charm-strange mesons, Phys. Rev. D 93 (3) (2016) 034035. arXiv:1510.08305, doi:10.1103/PhysRevD.93.034035.

[12] D. Ebert, R. N. Faustov, V. O. Galkin, Heavy-light meson spectroscopy and Regge trajectories in the relativistic quark model, Eur. Phys. J. C 66 (2010) 197–206. arXiv:0910.5612, doi:10.1140/epjc/s10052-010-1233-6.

[13] Q.-T. Song, D.-Y. Chen, X. Liu, T. Matsuki, Higher radial and orbital excitations in the charmed meson family, Phys. Rev. D 92 (7) (2015) 074011. arXiv:1503.05728, doi:10.1103/PhysRevD.92.074011

[14] A.M.Badalian and Yu.A. Simonov, "The exotic charmonium-like resonances in the mass region (3900-4700) MeV", arXiv:2205.02576v2 [hep-ph] 2022.

[15] D. Ebert, R. N. Faustov, V. O. Galkin, Spectroscopy and Regge trajectories of heavy baryons in the relativistic quark-diquark picture, Phys. Rev. D 84 (2011) 014025. arXiv:1105.0583, doi:10.1103/PhysRevD.84.014025.

[16] W. Roberts, M. Pervin, Heavy baryons in a quark model, Int. J. Mod. Phys. A 23 (2008) 2817–2860. arXiv:0711.2492, doi:10.1142/S0217751X08041219.

[17] T. Yoshida, E. Hiyama, A. Hosaka, M. Oka, K. Sadato, Spectrum of heavy baryons in the quark CONTENTS 135 model, Phys. Rev. D 92 (11) (2015) 114029. arXiv:151 0.01067, doi:10.1103/PhysRevD. 92.114029.

[18] B. Chen, K.-W. Wei, X. Liu, T. Matsuki, Low-lying charmed and charmed-strange baryon states, Eur. Phys. J. C 77 (3) (2017) 154. arXiv:1609.07967, doi:10.1140/epjc/ s10052-017-4708-x.

[19] C. J. Morningstar, M. J. Peardon, Glueball spectrum from an anisotropic lattice study, Phys. Rev. D 60 (1999) 034509. arXiv:hep-lat/9901004, doi:10.1103/PhysRevD.60.034509.

[20] Rohit Tiwari, Juhi Oudichania, and Ajai Kumar Rai, "Mass-spectra of light-heavy tetraquarks", arXiv:2205.00679v1 [hep-ph] 2 May 2022.

[21] B. Tatischeff, "Oscillation symmetry applied to some astrophysical masses, and allowing to highlight remarkable relations between masses", Physics and Astronomy International Journal PAIJ-04-00206-2.pdf. DOI:10.1506/paij.2020.04.00206.

[22] B. Tatischeff, "Do the exolanet properties verify the oscillation symmetry ?", https://vixra.org/abs/2111.0008.pdf.

[23] B. Tatischeff,"Where it is shown that the Oscillation Symmetry is also verified in the Physical properties of the Periodic Table of the Atomic Elements", https://vixra.org/pdf/2203.0113v1.pdf.

[24] S. Godfrey, K. Moats, E. S. Swanson, B and Bs meson spectroscopy, Phys. Rev. D 94 (5) (2016) 054025. arXiv:1607.02169, doi:10.1103/PhysRevD.94.054025.

[25] Y. Sun, Q.-T. Song, D.-Y. Chen, X. Liu, S.-L. Zhu, Higher bottom and bottom-strange mesons, Phys. Rev. D 89 (5) (2014) 054026. arXiv:1401.1595, doi:10.1103/PhysRevD.89.054026

[26] Y. Chen, et al., Glueball spectrum and matrix elements on anisotropic lattices, Phys. Rev. D 73 (2006) 014516. arXiv:hep-lat/0510074, doi:10.1103/PhysRevD.73.014516.

[27] H. B. Meyer, Glueball Regge Trajectories, Other thesis (2004). arXiv:hep-lat/0508002.

[28] E. Gregory, A. Irving, B. Lucini, C. McNeile, A. Rago, C. Richards, E. Rinaldi, Towards the glueball spectrum from unquenched lattice QCD, JHEP 10 (2012) 170. arXiv:1208.1858, doi:10.1007/JHEP10(2012)170.

[29] A. Athenodorou, M. Teper, The glueball spectrum of SU (3) gauge theory in 3 + 1 dimensions, JHEP 11 (2020) 172. arXiv:2007.06422, doi:10.1007/JHEP11(2020)172.

[30] H.-X. Chen, W. Chen, S.-L. Zhu, Two- and three-gluon glueballs of C = +, Phys. Rev. D 104 (9) CONTENTS 164 (2021) 094050. arXiv:2107.05271, doi:10.1103/PhysRevD.104.094050.

[31] A. V. Sarantsev, I. Denisenko, U. Thoma, E. Klempt, Scalar isoscalar mesons and the scalar glueball from radiative J/ΨΨ decays, Phys. Lett. B 816 (2021) 136227. arXiv:2103.09680, doi:10.1016/j.physletb.2021.136227.