How Might we Best Define the Current Quark Masses, and How do these help to Decode the Nuclear Mass Defects?

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Abstract:

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1. Introduction

In two earlier peer-reviewed papers [1], [2] the author demonstrated within parts per 10^5 AMU and better precision how the binding and fusion energies of the ^{2}H, ^{3}H, ^{3}He and ^{4}He light nuclides as well as the binding energy of ^{56}Fe could be explained as a function of *only two parameters*, namely, the current masses of the up and down quarks, found with extremely high precision in AMU to be m_u = 0.002 387 339 327 u and m_d = 0.005 267 312 526 u, see [10.3] and [10.4] and section 4 of [2] as well as section 12 of [1]. Using the conversion 1 u = 931.494 061(21) MeV [3] this equates with some loss of precision [4] to m_u = 2.223 792 40 MeV and m_d = 4.906 470 34 MeV, respectively. In an International Patent Application published at [5], this analysis was extended to ^{6}Li, ^{7}Li, ^{7}Be, ^{8}Be, ^{10}B, ^{9}Be, ^{10}Be, ^{11}B, ^{11}C, ^{12}C and ^{14}N with equally-high precision. And in [6] this analysis was extended using the Fermi vev v_F=246.219651 GeV and the Cabibbo, Kobayashi and Maskawa (CKM) mass and mixing matrix as two additional parameters, to explain the proton and neutron masses M_N = 939.565379 MeV and M_P = 938.272046 MeV [7], *completely within all known experimental errors*.

Yet, there is one underlying point which has not been sufficiently explained in any of these prior papers: the Particle Data Group (PDG) lists these two current-quark masses to be to $m_u = 2.3^{+0.7}_{-0.5}\,\mathrm{MeV}$ and $m_d = 4.8^{+0.5}_{-0.3}\,\mathrm{MeV}$ with large error bars of almost 20% for the down quark and almost 50% for the up quarks, "in a mass-independent subtraction scheme such as $\overline{\mathrm{MS}}$ [modified minimal subtraction] at a scale $\mu \approx 2\mathrm{GeV}$." [8] (Note that $\overline{\mathrm{MS}}$ and similar renormalization schemes are used to absorb the divergences from perturbative calculations beyond leading order.) In other words, the PDG values are extracted for a given renormalization scale and are actually a function of this scale and of the renormalization scheme. So although these m_u = 2.223 792 40 MeV and m_d = 4.906 470 34 MeV found by the author are well-placed near the center of these PDG error bars, the claimed precision raises the question: can we really talk about and understand these quark masses with such high precision, in a fashion which is *independent* of renormalization scale and scheme? More plainly put: is there some sensible way to simply state that "the up and down quark masses are X and Y," with X and Y being some mass-energy numbers which have an extremely small error bar due to nothing other than the accuracy of our measuring equipment? Is there a sensible, definite, unambiguous, very precise scheme we can use to define the current quark masses, consistent with empirical data, which scheme is renormalization scale-independent?

Specifically, the author's prior findings that m_u = 2.223 792 40 MeV and m_d = 4.906 470 34 MeV (these same masses were earlier shown even more precisely in AMU) with a precision over a million times as tight as the PDG error bars, even if *mathematically* correct in relation to the nuclear masses with which these quark masses are interrelated, presuppose an understanding of how these quark masses are to be *physically* defined and measured and understood. Without such an understanding, the author's prior work is incomplete, and to date, the author has not directly and plainly articulated this understanding.

The intention of the present paper is to remedy this deficiency by making clear that the mass defects found in nuclear weights which are related in a known way to nuclear binding and fusion / fission energies, are in fact a sort of "nuclear DNA" or "nuclear genome" the proper decoding of which teaches about nuclear and nucleon structure and the masses of the quarks in a way that has not to date been fully appreciated. In contrast to the *nuclear scattering schemes* presently used to establish quark masses, which are all based on renormalization-dependent, energy scale-dependent experiments involving scattering of nuclides and nuclei, the scheme which has been implicitly used by the author which this paper will now make explicit, is a *nuclear mass defect scheme* in which quark masses are defined in relation to the objective, very precise, experiment-independent, scale-independent, long-known energy numbers that have been experimentally found and catalogued for the nuclear mass defects, weights, binding energies, and fusion / fission energies.

All scattering experiments essentially bombard a target and use forensic analysis of the known bombardment and the found debris to learn about the nature of the target prior to bombardment. In contrast, mass defects are no more and no less than an expression of nuclear weights requiring no bombardment of anything. In this context, the prevailing scheme for characterizing quark masses has wide error bars because it is based on "bombing" the nuclides and nuclei, while the scheme to be elaborated here has very high precision because it is a "weighing" scheme which uses only nuclide and nuclear weights and so inherits the precision with which these weights are known. Colloquially speaking, the scheme to be articulated here has very tight error bars because it is based on non-intrusive nuclear "weighing" rather than highly-intrusive nuclear "bombing," and because nuclear weights themselves are very precisely known while scattering experiments introduce renormalization and scale issues which ruin precision and the ability to establish an unambiguous approach for specifying quark masses.

References

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[3] http://pdg.lbl.gov/2014/reviews/rpp2014-rev-phys-constants.pdf

[4] See, e.g., http://pdg.lbl.gov/2014/listings/rpp2014-list-p.pdf: Nuclear masses are "known much more precisely in u (atomic mass units) than in MeV. The conversion from u to MeV . . . involves the relatively poorly known electronic charge."

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