Truly Minimal Unification : Asymptotically Strong Panacea ?

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We propose Susy GUTs have a UV attractor at $E \sim \Lambda_{\text{cU}} \sim 10^{17}\text{GeV}$ where gauge symmetries “confine” forming singlet condensates at scales $E \sim \Lambda_{\text{cU}}$. The length $l_U \sim \Lambda_{\text{cU}}^{-1}$ characterizes the size of gauge non-singlet particles yielding a picture dual to the Dual Standard model of Vachaspati. This Asymptotic Slavery (AS) fixed point is driven by realistic Fermion Mass (FM) Higgs content which implies AS. This defines a dynamical morphogenetic scenario dependent on the dynamics of UV strong N=1 Susy Gauge-Chiral (SGC) theories. Such systems are already understood in the AF case but ignored in the AS case. Analogy to the AFSGC suggests the perturbative SM gauge group of the Grand Desert confines in SUGUT scales i.e. SUG symmetry is “non-restored”. Restoration before confinement and self-inconsistency are the two other (less likely) logical possibilities. Truly Minimal (TM) SU(5) and SO(10) models with matter and FM Higgs only are defined; AM (adjoint multiplet type) Higgs may be introduced for a Classical Phase Transition (CPT) description. Renormalizability and R-Parity leave only the low energy (SM) data as free parameters in the TM (Quantum PT) case. Besides from resolution of the Heirarchy problem and choice of Susy vacuum, fresh perspectives on particle elementarity and duality, doublet triplet splitting, proton decay suppression, soft Susy masses etc open up. “Elastic” (spin 2 and spin 3/2) fluctuations of the AS (or pleromonal) condensate couple universally to SM particles with length scale $l_U \sim l_{\text{PT}}$ imply an effective $N = 1$ (super)gravity in the Grand Desert, in which gaugino condensates yield soft Susy breaking. A study of the dynamics of ASSGC dynamics to either sustain firmly, or finally dispense with, the dogma of Asymptotic Freedom, is thus required.

A. Introduction.

For 30 years Nature has tantalized us with the prospect of a Grand Unification of all the fundamental interactions of particle physics [1-2]. However, inspite of notable steps [3-4] towards the vision of the seminal works a truly convincing minimal and predictive model that reveals the inner logic of the Standard Model (SM) palimpsest has not been singled out. The demonstration that the now accurately measured gauge couplings unify convincingly only in Supersymmetric models and the discovery of neutrino mass effects [5-6] (with associated scales near the Unification scale) have meanwhile provided a welcome resilience and elasticity to the initial vision of symmetry restoration at high energy and given us some confidence in the necessity of Supersymmetry. They have also driven home the lesson that the SM, indeed any good theory, should always be regarded as an effective theory a la Landau useful for coding the regularities of nature apparent at some given range of scales of resolution.

Supersymmetric gauge theories based on the gauge group SU(5) and even more so on SO(10) [7-10] carry our hopes for minimal and relatively straightforward unification. On the other hand the apparent gibberish of the fermion mass spectrum and vast parameter space of the MSSM coupled with stubborn problems such as Doublet-Triplet splitting, Supersymmetry breaking and suppression of flavour changing currents sometimes make the unification project seem like a game played by whimsical rules of the practitioners. Meanwhile the increasingly stringent constraints on the proton lifetime [11] have engendered both doubts concerning the viability of so called minimal unification [12] and counter arguments [13] based on the apparent many fold freedom to adjust the parameters of the MSSM. Thus only reinforcing current quiescence regarding the whole project. Any additional natural criterion of minimality of the Higgs representation choice in GUT models which is well motivated by elementary intuitions of dynamical consistency, would be welcome. On the other hand a robust and generic indication from within realistic GUT models would be equally welcome. We argue in this letter that such criteria are in fact visible in the structure of the SM and implied by it in GUTs. This Letter is devoted to sketching the picture that emerges intuitively leaving calculational details for later publication [14].

B. Massless Charged Fermions

As regards the intuition of dynamical consistency we observe that: there is no massless fermion interacting with a massless gauge field in Nature (unconfined ? see below). This remarkable feature is built into the SM by means of a small miracle of economy. Namely that the same Higgs multiplet that breaks the $G_{123}$ symmetry down to $SU(3)_{c} \times U(1)_{em}$ is capable of ensuring mass to all fermions except the neutrinos (which are (tellingly !) neutral with respect to both these unbroken symmetries). Even the discovery of neutrino mass is not incoherent with this economy since the SM Higgs can give masses

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also to neutrinos via dimension 5 operators. This economy of design has perhaps misled us to regard the question of fermion masses as somehow peripheral to that of SSB rather than vice versa.

Usually this economy is attributed merely to the parsimony of Nature in choosing the Higgs she needs. The crucial question on our view, however, is: What does She really need to do? (to build the world we live in). Surely it is not necessary to avoid massless gauge fields as such since these are the basis of structure in the universe. On the other hand Massless Charged Fermions (MCFs) are paradoxical objects that can become steadily more energetic in an electric field without experiencing any acceleration and cosi via. Similarly QED cross sections (e.g. for Compton scattering, pair annihilation etc) are afflicted with poles in the electron mass showing that the problem is not merely classical. Thus both Classical and Quantum mechanics face notable difficulties in formulating well defined physical theories of such objects. Similar difficulties would presumably be faced by massless unconfined YM theories coupled to strictly massless fermions. While MCFs may be common in some alternative universe with magical properties they would certainly be out of place in the everyday and stable one in which we live: hemmed in by Iron Laws in Time and Space!

Speculations regarding massless quarks may remain consistent with our observation since SU(3), confines in the infrared. Confining AF gauge fields may coexist with MCFs because in that case there are non-perturbative limits to their spatio-temporal freedom and they acquire effective masses in their bag within the confining Quantum vacuum. In fact quarks are not appropriate degrees of freedom for observers "outside their bag". The example of QCD has further important lessons. It is now fairly well established that the Chiral Symmetry Breaking (CSB) scale \( \Lambda_{\text{CSB}} \) at which the pions are generated is above the confining scale \( \Lambda_c \). Indeed many valuable insights into Hadron Dynamics and structure have been derived using an effective Lagrangian which couples QCD to a linear sigma model of condensate fields (pions \( \pi \) and \( \sigma \)). Thus there are three regimes in QCD: I) The confined theory with hadrons and pions. II) The intermediate scale theory with a quark-pion sigma model just above the confining transition. III) UV theory with weakly coupled QCD and quarks. The coupling falls steady from IR to UV regimes. It is clear that at high energies E the IR condensates (\( \sim \Lambda_c \ll E \)) have negligible effects. This is easily visualized since these energies correspond to violent fluctuations on length scales much smaller than the IR condensate ones. Now let us turn this picture around and consider a UV strong QCD -Quark theory. If once again one has three regimes in the same sequence as one approaches UV confinement the physical interpretation is drastically revised! In particular the UV scale condensates being constant on scales much smaller than the wave length at low energies (much below the UV confinement scale \( \Lambda_{\text{UV}} \)) cannot be irrelevant to the dynamics in the perturbative regime (which in this case is in the IR). In fact the UV condensate will define the low energy theory by determining the massless degrees of freedom. The peculiarity of UV condensation however lies in that the labels that are confined at ever smaller scales are precisely the ones that are visible (to us with our IR eyes). We expect the perturbative degrees of freedom (with additions in some intermediate regime) to be the correct ones in the Intermediate regime (till the usual IR confinement takes over). Note the peculiar but natural picture of a quark: a quark would be slathered in glue so that it had an effective size \( \sim \Lambda_{\text{UV}}^{-1} \), but on larger scales it's electric flux would stream out radially since the coupling would be weak: a very compact core of glue string tangle horripilating field lines like the usual point particle picture at larger scales! Thus the role of the AS (or pleromal) condensate is to screen length scales smaller than \( \Lambda_{\text{UV}} \) from view at larger scales and to thus give a size to the pointlike gauge non-singlet elementary particles consisting of a pleromal gauge singlet screen around their putative pointlike center. In other words the analog of the hadronic bag is beyond this pleromal screen. This intuitive picture of AS “confinement” lies behind our work like a guiding thread and shows that AS is not “unthinkable”.

The extension of the above intuitive picture to the entire SM embedded in an AS GUT yields a picture of SM particles intriguingly dual to the Dual SM (DSM) of Vachaspati where the usual SM particles emerge as monopoles of Dual gauge group with spontaneously broken GUT scale cores whereas in the present case the cores (also of size \( \Lambda_{\text{UV}} \)) are instead formed from AS condensates of the usual gauge group. This fits in well with the usual understanding of Electric Magnetic Duality. Thus the AS in the Electric sector implies AF in the magnetic or dual sector and justifies construction of the classical monopole solutions basic to the DSM conjecture. AF Electric theories would imply large magnetic couplings and thus make the DSM picture less appealing. Conversely the IR freedom of the Electric theory (at scales \( \gg \Lambda_{\text{GUT}} \)) implies that the Dual theory is IR strong. This may be the reason for the non observation of monopoles. The topological origin of Electric charge in the DSM naturally prompts speculation on the nature of the matter multiplets in the SM: could their “Electric” charges also be long distance labels of the strongly coupled electric tangle at their core in our proposed AS picture? Like the DSM we are now on shaky foundations, there is no clear answer to why the mass of such monopoles/tangles is not of the same magnitude as their inverse size nor how the proper statistics emerges. Perhaps a supersymmetrization of the theory will help in resolving these questions.

As regards the MCF problem one remarks that since in practice QCD is a part of the SM the answer depends on the running of the EW symmetry breaking vevs which give rise to the bare quark masses. The two alternatives are that of the well loved EW Radiative Symmetry Breaking (EWRSB) in which case the EW breaking Higgs vevs will vanish at sufficiently high scales when the
mass squared parameters of the Higgs doublets turn positive or they do not i.e the EW vevs are “hard wired” into the high energy behaviour. In the latter case there is presumably no MCF problem in UV free theories. However in the EWRSB case one again would have massless unconfined gauge fields coupled to massless quarks at the scale where the mass squared parameter turns sign and this we have argued is nonsensical/other worldly behaviour. Even if strong coupling screened the problem at the highest scales the problem reappears at lower scales unless at least a seed mass for fermions emerges at GUT scales. This again suggests the intimate connection between fermion masses, EW symmetry breaking and AS and disfavours purely radiative generation of even the first generation fermion masses.

C. Truly Minimal Unification

Moreover, a Higgs sector that is sufficiently complex to account (e.g. \([12, 26, 28]\) for the observed pattern of fermion masses and mixings (e.g. \([10, 12, 126]\) in SO(10) GUTs or e.g (5, 5) together with (45, \(\overline{45}\)) in SU(5)) implies that as soon as the the FM residuals’ mass thresholds are crossed (generically this happens around or somewhat above \(M_c\)) the GUT gauge coupling grows very strongly and perturbation theory must be abandoned. The expectation is naturally that the theory “confines” at \(\Lambda_{U} \sim 10^{16} - 10^{17}\text{GeV}\). However so far this type of behaviour, so radically counterposed to the familiar IR confinement, has been regarded as inconceivable, inconsistent or at best to be rescued by mysterious Quantum Gravity Planck foam etc. By reversing the logic of our expectations and taking the MCF problem as the driving reason for symmetry breaking and the FM Higgs driven condensation as an internal message of the inevitability of strong coupling/confinement we are then led to accept the necessity of thinking through the consequences of the intuitively new “confining” behaviour in the UV for our picture of elementarity and symmetry breaking. Fortunately the fact that Susy GUTs are the favoured unification candidates for deep reasons implies that this dynamical symmetry breaking problem is may be capable of resolution by the techniques \([29]\) already developed and applied to the the case of AF theories. This taming of the symmetry breaking problem was previously applied by us to the case of realistic models with perturbative high scale gauge SSB \([2]\) (actually those theories are also generically AS): encouraged, we demand that in a truly minimal theory:

(i) The Higgs sector should generate SM fermion masses. These Higgs we shall call FM Higgs. Their vevs must break EW symmetry in an economical and minimal way to give the observed fermion mass pattern at the renormalizable and tree level, so that the FM-Matter cubic couplings are determined (we shall eschew models with duplication of Higgs so that there may be a clear assignment of functions based on representation structure). Other Higgs such as the adjoint multiplets used in SU(5) and SO(10) GUTs \([12]\) or the symmetric/4 index a.s tensors used in minimal Susy SO(10) GUTs \([10, 28]\) we shall generically call AM Higgs. FM representations are in general complex while AM representations are real in common models. One typically finds AM representations in the products of FM ones. The FM Higgs set chosen should of course be anomaly free and this provides a welcome further constraint.

The alert reader will object that the FM Higgs cannot possibly be used to break symmetry at the GUT scale since then \(G_{123}\) symmetry also breaks at the GUT scale. We will answer this objection in detail below arguing that it need not hold if the strongly coupled theory at the GUT scale generates condensates of products of the FM Higgs in AM channels i.e that the GUT phase transition is quantum, while the individual AM fields have vevs that are much smaller than the GUT scale. This is made all the more likely by the enormous Casimir indices of typical FM irreps beyond the lowest. Inclusion of AM Higgs allows a Classical Phase Transition (mean field) description of the same FM driven condensation and may be preferred in practice since the whole trend of the argument is that the extractable physics lies in a Universality Class determined by the FM Higgs content.

(ii) We expect and accept that at high energies the FM Higgs drives the theory into the strong coupling regime where large gauge singlet condensates breaking the symmetry down to \(G_{123}\) as well much smaller \(G_{123}\) breaking corrections develop (which tame the MCF problem). If this happens much above the perturbative unification scale then only may we speak of GUT symmetry restoration. However since symmetry breaking effects are suppressed by \(M_{U}/\Lambda_{U}\) only it is hard to see how a clear distinction could usefully be made. Thus we must face the analysis of the ASSGC system head on.

All, however, is not lost. Firstly low energy fixed point structures \([1]\) of the SM and MSSM RG equations for Yukawa and gauge couplings makes them insensitive to the high energy dynamics. Secondly behaviour analogous to that of AFSGC theories would here mean that the perturbative regime unbroken symmetries (to leading order in \(\Lambda_{U}\)) could continue unbroken into the strongly coupled regime as confined while the coset \((G_{GUT}/G_{123})\) gauge degrees of freedom, although now massive, would not be decoupled at the the confinement scale since their masses have the same magnitude. The interpolating parameters being of course the scale of the vev on the one hand and the scale at which the theory is defined on the other. Therefore they would contribute to the RG effects which confine the SM gauge symmetries. The same applies to other FM residuals \((G_{123} \text{ non singlets })\) that became heavy due to the phase transition in the AM channel. However since the UV strong dynamics is, so far, unknown it is marginally conceivable that there some intermediate regime where the GUT symmetry is neither confined nor broken. The existence of the GUT symmetry is not merely a semantic point since the gauge and FM residuals would mediate proton decay. The task will be to see if these novel ASSGC systems can yield
the Grand Desert type effective softly broken Susy theories with very weakly broken $G_{123}$ and non zero fermion masses at all scales below $\Lambda_{cU}$. Notice that this discussion provides a fresh non-perturbative perspective on symmetry non-restoration and thus also on that route to the resolution of the GUT monopole problem [21,33].

Such a UV strong coupling dynamics is already analyzable to some extent due to the great advances in understanding supersymmetric strong coupling dynamics [23] using holomorphy, factorization and single instanton or dilute instanton gas techniques. However since here we have UV rather than IR slavery there may be significant differences between the strong dynamics of these two distinct classes of Susy Gauge theories. In particular the use of small scale instantons to saturate and thus calculate crucial quantities such as the di-gluino condensate may need to be modified because the short distance regime is now also a strong coupling regime. Indeed a perusal of the arguments used in calculating these condensates quickly discloses frequent use of the smallness of the running coupling $g(v^2)$ at the scale $v$ of the Chiral condensates that define the vacuum. In the present case that regime would be achieved in the region of moduli space that the chiral condensates were small compared to $\Lambda_{cU}$ i.e the intermediate or Grand Desert region. The condensation effects can still be studied using the general techniques developed but we will not prejudice the argument by quoting preliminary results [11] here. While this means that no immediate decision on our proposal can be taken, our arguments will have served our purpose if they motivate clarification of the nature of ASSGC theories. Even if is rigorously proven that ASSGC dynamics are so inconsistent that no such theory should ever be entertained then so robust a support to this tottering Shibboleth of Particle Physics will still be a welcome constraint on future speculations.

D. SU(5) and SO(10) Models

To proceed, let us calculate the possible FM Higgs sets in the case of SU(5) and SO(10) Grand Unification. In SO(10) GUTs the fermions of one SM generation (plus $\nu^c_L$) fit in a 16 plet of SO(10) and mass terms arise from SO(10) invariant couplings $16 \cdot 16 \cdot FMHiggs$ in the superpotential. Since $16 \times 16 = 10 + 120 + 126$ and the representations 10, 120 are real it immediately follows that the possible FM Higgs in SO(10) models are nothing but $10, 120, 126$. These have second Casimir indices indices 1,28,35 respectively. R parity preservation requires $120$ to be paired with $126$. The very Higgs $(120, 126)$ that are used to reach realistic (or quasi) fermion mass relations [23,27] drive the gauge couplings UV strong. Since SO(10) has no gauge anomalies any combination of these may be used. For the AM sector (if the reader insists on one!) one can use, for instance, some combination of $45, 54, 210$ in SO(10) see e.g. [23,34]. These also have a strong effect on the GUT coupling above $M_U$ and are all contained in the product of the above FM representations thus for instance

$$120 \times 120 = 1 + 45 + 54 + 210 + ...$$

$$126 \times 126 = 1 + 45 + 210 + ...$$

In the case of SU(5) we must again calculate the conjugate of the product of the sum of reducible representations $1, 5, 10$ with itself and separate out anomaly free subsets. This gives :

$$\Phi_1(5, 5), \Phi_2(45, 15), \Phi_3(5, 10), \Phi_4(15, 45, 50)$$

The SU(5) indices of these combinations are 1, 2, 4, 33. The 45-plet is the representation used by Georgi and Jarlskog [23]. Note that the 120 of SO(10) contains $\Phi_2$ while $\Phi_3, \Phi_4$ lie in $126$ which can therefore also support the Georgi Jarlskog mechanism [23,24]. For UV strong coupling with just 3 light families one needs at least one of $\Phi_2, \Phi_4$. In that case (assuming a Grand Desert and sharp FM residuals mass thresholds at $M_U$) one finds that the one loop running GUT coupling explodes within one order of magnitude of the perturbative unifying scale $M_U \sim 10^{16} GeV$ i.e $\Lambda_{cU} \sim .7 \times 10^{17} GeV$. For the AM sector one can use, for instance, $24, 75$ in SU(5) [21]. They too are UV slave drivers and they too are contained in products of realistic FM Higgs sets.

We therefore need to, at least, analyze the gauge coupling dynamics of (AM-less) models like

I SuSy SO(10) with $10 + 120$

II SuSy SO(10) with $10 + 126 + 126$

III SuSy SO(10) with $10 + 120 + 126 + 126$

IV SuSy SO(10) with $120 + 126 + 126$

V SuSy SU(5) with $\Phi_1 \oplus \Phi_2$ i.e $5 + 5 + 45 + 45$

and so on : take any anomaly free combination of the FM fields but use $126 + 126$ in SO(10) FM Higgs sets. See remarks on $R$-parity below which justify this. In practice a mean field (CPT) description favours introduction of sufficient AM Higgs to break the GUT symmetry to $G_{123}$.

E. Actions

Following Landau, having isolated the possible true order parameters of the theory the most general supersymmetric action may be specified in terms of an GUT invariant Kahler potential $K(F, F^*, \Phi, \Phi^*, A, A^*)$ and a super potential $W(F, \Phi, A)$ in a schematic notation in which the matter, FM Higgs and AM Higgs chiral superfields are denoted by $F, \Phi, A$ respectively. Naturally these are expansions in powers of invariants of the gauge group, with higher powers than 2 in $K$ and 3 in $W$ being suppressed by powers of a scale $M$ whose exact value is left indeterminate for now since we shall focus on renormalizable models. We have argued that the symmetry breaking and separation out of the MSSM in the Grand Desert is
dynamically determined. The mass scale of FM residuals (e.g., the color triplet Higgs) is however controllable by the FM mass parameter thus opening up a method to resolve the doublet-triplet splitting problem in a way analogous to models which make the low energy Higgs doublets Goldstone or pseudo-Goldstone multiplets in some large symmetry scenario.

We remark that we regard R-parity as such a necessary ingredient of a SUSY GUT (since it effectively defines the distinction between matter and Higgs fields, and punishes any attempt to mix them with catastrophe) that we advocate complete suppression of R-parity violating couplings between the F and Φ and/or A superfields in the case of SU(5). While for SO(10), since R-parity preserving SUGTs require a 126 + 126 combination, even though anomaly cancellation does not, we shall use this combination rather than a single 126 i.e. the FM fields for SO(10) will be taken to be 10, 120, 126 ∈ 126. Also along the same lines we do not envisage any non-renormalizable terms involving matter fields in the superpotential. The FM Higgs-Matter Yukawa couplings may possibly enter the renormalization of the Kahler potential or into the fine structure (i.e. $O(M_W/M_G)$) and $O(M_{S}/M_{U})$) of the vacuum state determined but they will be irrelevant to the $O(M_U)$ spontaneous symmetry breaking of the FM Higgs condensates in the AM channels as well as to the $O(M_{W}) G_{123}$ breaking vevs of the FM Higgs fluctuations themselves and may thus be safely ignored in a leading order determination of the Gauge-FM Higgs dynamics at $\Lambda_{\chi\phi}$.

One important feature of FM Higgs superpotentials is that $\Phi^3$ cubic couplings vanish so that at the renormalizable level the superpotential contains only mass terms e.g. $10^2 + 120^2$ in model I, and $5 \cdot 5 + 45 \cdot 15$ in model V. The extreme simplicity of the renormalizable R parity preserving pure FM Superpotential ($W = YFF\Phi + m\Phi\Phi$) implies that the $Y,m$ are the only free parameters besides the values of the low energy gauge couplings, gauge boson masses and Newton’s constant. This means that if our scenario is dynamically possible then our Vision of the of the observed fermion mass pattern determining the pattern of Symmetry breaking will be realized.

**F. Dynamics**

As explained above the current knowledge on SUSY gauge dynamics of IR strong theories is not immediately applicable to the UV strong case. Indeed a common reaction is to dismiss such a possibility out of hand as too bizzare or counter intuitive. One argument is that since a confining theory forms a condensate because it seeks to screen the strongly interacting colour charges it will not break itself spontaneously in the strong coupling regime. However as we have already mentioned AF SUSY Gauge-Chiral systems habitually break their own symmetry dynamically to a subgroup which is perturbative in some regions of moduli space and confining in others. This is just the sort of behaviour we require and would imply that just the SM gauge fields confine.

Furthermore the non-lowest FM Higgs representations are enormous in terms of their large second Casimirs. Thus if e.g. fundamentals (such as MCFs!) are confined just above $M_U$ (as we argued they should), then even non-singlet combinations of FM fields with 2 or more “hanging” indices can be confined all the more since they can still contain many more contracted indices than a meson. Note that once higher FM representations are introduced quartic and higher chiral FM invariants become possible and are coordinates for the D-flat moduli space. Since quadratic products of FM Higgs contain AM Higgs it is certainly conceivable that a quartic or higher (even) order modulus takes its non zero value due to a quantum condensation of FM products in AM channels. In order that the symmetry structure and gauge boson mass spectra be commensurate the quantum condensates in the chiral $(\Phi\Phi)$ and non-Chiral$(\Phi\Phi^*)$ sectors would need to be correlated.

Another objection is that such a theory would then have no regime in which its SO(10) provenance could be determined. We cannot see, however, why the confining phenomena at the GUT scale preclude, for example, proton decay via the massive bosons with masses $O(M_U)$. The above arguments show that an a priori rejection of the possibility of a quantum phase transition is unwarranted. In connection with the possibilities of UV strong dynamics considered in the literature we refer the reader to [33] where also a preonic model of strong unification in which gauge couplings first become strong and then weak again at still higher energies was described. Presumably the above behaviour was there deemed attractive for reason of the prejudice that the asymptotic dynamics must be free.

Our models await rigorous analysis of UV strong gauge theories and their very novel but not necessarily counter-intuitive features [43]. To illustrate, very schematically, the possibilities we use the well known AFSGC SU(5) model with one $\phi(5) + \bar{\phi}(\bar{5})$ pair (in fact an fermion mass giving Higgs set for the minimal SUSY GUT but not enough for UV slavery: this could be remedied (without complicating FM Higgs sector) by e.g. increasing the matter content to more than 7 matter families). Then we could drop the matter from consideration on R-parity grounds. However that still leaves us with the inapplicability of IR strong results. So we emphasize that we are merely using the known results for the IR strong model to illustrate interpretational possibilities if at least the weak assumption that the connection between the strong and weak coupling regime gauge symmetries is respected. This toy model is known to have a non-singular Classical moduli space consisting of a single chiral invariant $A = \phi\bar{\phi}$ at any non zero value of which the gauge symmetry breaks to SU(4) while 9 chiral supermultiplets combine with the 9 SU(5)/SU(4) gauge multiplets via the super Higgs effect. Inclusion of quantum corrections can be shown to correct the the superpotential only to
\[ W = m\tilde{\phi} + b(g^2) \frac{\hat{\Lambda}_{cU}}{(\phi\phi)^2} \tag{4} \]

Note that in the AS case \( m \sim \Lambda_{cU} \) implies that the GUT phase transition is in the strong coupling regime (so that Quantum effects are appreciable). The second term is generated non-perturbatively for symmetry reasons with only its coefficient obtained from a constrained instanton calculation \[24]\ (now dubious in the UV) in the weak coupling regime and \( \hat{\Lambda}_{cU} \equiv \Lambda_{cU}^{1/2} \). In the \( m = 0 \) case the minimum is at \( A = \infty \) and when \( m \neq 0 \) it comes in to finite values. For \( m = 0 \) there is global R symmetry which breaks spontaneously as \( U(1)_{R} \times U(1)_{V} \rightarrow U(1)_{V} \) and so leaves a massless Goldstone chiral supermultiplet which we can liken to a proto-low energy sector. Since the R symmetry is violated at \( m \neq 0 \) the corresponding Goldstone supermultiplet becomes massive with mass \( \sim m \). Then \( m \neq 0 \) makes the Goldstone massive since the mass term violates the R symmetry (softly). However in models with more than one pair of fundamental and anti-fundamental there is a global \( SU(N_{f}) \times SU(N_{f}) \rightarrow SU(N_{f})_{\text{vector}} \) symmetry breaking whose \( N_{f}^{2} - 1 \) Goldstone chiral multiplets do not suffer from this problem and our remarks can be trivially generalized to that case. Of course the analogy is still imperfect because these Goldstons are still singlets w.r.t the unbroken \( SU(N_{e} - N_{f}) \) gauge group but there is no reason the true FM multiplet models may not jump this small group theoretical hurdle easily in view of their multi-index representations. Indeed this would happen quite naturally in view of our remarks on higher order chiral invariants present in realistic models and the AM channel condensation. Details will be given elsewhere \[11]\.

G: Gravity and Susy Breaking

The existence of a fundamental length \( l_{U} \sim \Lambda_{cU}^{-1} \) associated with the gauge singlet condensate that precipitates out leaving our \( G_{123} \) labelled world as its low energy limit provides a normal and minimal route to realizing the old dream of induced or effective (super)gravity \[33\]. This approach-though initially promising- was largely abandoned in the mid eighties due to difficulties in obtaining the correct sign and magnitude of the induced gravitational coupling and cosmological constant \[32\] in AF theories. Even worse it was pointed out that any theory with quadratic and quartic divergences would suffer from non-perturbative and irremovable ambiguities in the formulae for these basic quantities \[32\]. The same author also suggested that these difficulties would not be present in a supersymmetric theory. Strangely this suggestion for curing the difficulty does not seem to have been taken up, possibly from despair at the difficulties of AF theories.

Our Susy GUTs are however quite different animals from those that were scrutinized earlier. They are both AS and supersymmetric and as such could evade earlier difficulties. Moreover the global supersymmetry of the underlying theory will presumably ensure unambiguous expressions for gravitational parameters and ensure the induced cosmological constant remains zero! This would be a severe difficulty in a non supersymmetric fundamental theory. If one accepts the natural length scale \( l_{U} \) for the size of the massless composite graviton (and gravitino) that arise in the effective \( N=1 \) Supergravity at low energies (given the basic induced gravity premise of general coordinate invariance of the global theory in the gravity background) then it is clear that probes at low energies will not be able to resolve their structure. In the induced gravity picture \[33,32\] the graviton multiplet may be identified with the massless “elastic” fluctuations (spin 2,3/2) of the (very stiff) GUT scale (super)condensate and its universal coupling follows trivially from the singlet nature of the condensate. Indeed the behaviour in this regard has a curious close relation to the QCD based \[8\] “strong gravity” \[39\] expected as a result of QCD condensates within the Hadronic bag. In that picture di-gluon gauge singlet bound states were assumed to furnish spin-2 hadronic “pseudo-gravity” interactions among strongly interacting hadrons. However since gravity is UV strong while QCD is IR strong the regimes of that proposal do not quite match. In the present case both the graviton and the gauge theory are in the weakly coupled regime in the IR. The condensate which veils length scales shorter than \( l_{U} \) from the gauge non-singlet perturbative world provides the (super)gravity multiplet. It is indeed satisfying that the known Planck scale and \( l_{U} \) are so close. The long renormalization down to the scales at which \( G_{N} \) has been measured could easily account for the small discrepancy. On decoupling grounds the low energy effective theory would then be \( N = 1 \) Supergravity coupled to a \( G_{123} \) perturbative AFSGC system \[40\]. Since the gauge multiplet condensates (gaugino condensate) couple to an F term in the Supergravity they can introduce soft Supersymmetry condensates into the low energy effective theory which is phenomenologically necessary and may also be needed to generate the observed EW vevs \[11\] .

H: Concluding Remarks

The frankly programmatic rather than technical content of this letter was originally motivated by the need to face the problem of exploding GUT coupling above the perturbative unification scale in the SO(10) model constructed by us elsewhere \[10\]. It is clearly completely dependent on the determinable dynamics of the precisely defined set of truly minimal UV strong SUSY GUTs we have set out. That analysis can draw upon the impressive machinery for the analysis of supersymmetric vacua developed over the last 2 decades \[32\] when that has been extended to the UV strong case for the fairly complicated realistic cases we have suggested. We hope to have convinced the reader that our novel reading of the purpose of symmetry breaking in the SM puzzle and the generic and genuine difficulty of otherwise perfectly sensible Susy GUTs does warrant a pursuit of these difficult dynamical questions. Such an analysis alone can confirm or dismiss
the scenario painted above.

Having accepted the need to think through the consequences of ASSGC dynamics we found that very mild assumptions of similarity to the known AFSGC dynamics opened up dazzling vistas of resolving many of the most obtuse problems concerning the Unification of the Fundamental interactions, including gravity, in the context of a very pleasing intuitive picture of elementarity of particles. Many of these had been given up as dead ends in the course of the years, based (it seems to us) on an untenable assumption that AS dynamics is necessarily meaningless simply because it is AF dynamics that rules the internal dynamics of the hadronic world. Looking boldly into this blind spot immediately confers the said dazzling visions! If these Visions are realizable then we will have washed away much of the motivation for “worm wars” or “magic carpet” mathematically inspired speculation by taking seriously two elementary generic features of Unifying models associated with the SM: which codes what we know about elementary particles so successfully.

To conclude we have taken the obvious but non-trivial feature of the absence of MCFs to have a deep significance and to be the true rationale of symmetry breaking in nature. Accepting the generic representation structure of the FM Higgs we accept the drastic consequences that ensue and find that in fact they are eminently intuitively and could resolve many obtuse problems. We thus suggest that the low energy spectrum and couplings are the ultimate rationale and determinant of symmetry breaking at UV scales in Nature. This should satisfy the most pertinacious of postivistic “Machian” objectors to the validity of the Grand Unification project. Specifically, accepting the obvious FM Higgs that typically and easily drive the gauge coupling to UV slavery (avoiding MCF problem in the UV) leads naturally to a scenario of a Quantum GUT Phase Transition.

Forse La Natura canta suoi segreti solo sul canale FM
O forse abbiamo udito solo La Sirena che ‘tirava noi
sugli sassi ultra violetti!

(Perhaps Nature can be heard singing her Secrets only
on the FM band. Or perhaps we have only heard a Siren
drawing us onto rocky Ultra Violet shoals!).

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